THE
GEOLOGICAL MAGAZINE
VOLUME LXIX.

No. VII.—JULY, 1932.

ORIGINAL ARTICLES.

Algal Limestones from Gigoomgan, Queensland.

By Professor H. C. Richards, D.Sc., and W. H. Bryan, D.Sc.,
Department of Geology, University of Queensland.

(PLATES XVII–XX.)

Abstract.

THIS paper describes the occurrence in Queensland of a large mass of limestone of late Palaeozoic age made up almost entirely of the microscopic remains of calcareous algae.

I. Introduction.

During the course of an investigation into the economic value of certain limestone deposits lying to the west of the town of Maryborough, in Queensland, the authors were impressed by the fact that nearly all sections prepared for the microscope from limestone specimens collected at Gigoomgan showed the same curious micro-structure. The tentative determination of this structure as being due to the accumulation of algal remains and the support in this conclusion by a number of other geologists and palaeontologists, to whom the slides were submitted, determined the authors to investigate the occurrence in greater detail.

Subsequent visits to the locality enabled further observations to be made and systematic collecting to be done.

The limestone lies in lat. 25° 43′ S., long. 152° 16′ W., about 35 miles W.S.W. of Maryborough on the cattle station property "Gigoomgan" of Mr. G. Mant, to whom the authors' most sincere thanks are due for kind hospitality and for assistance in the field, assistance made all the more valuable by his thorough knowledge of the area.

Among others who have generously assisted the authors in the preparation of this account, by their advice and expert knowledge, especial mention must be made of Sir Edgeworth David, to whose keen interest the writing of the paper is largely due, of Dr. D. A. Herbert and Dr. F. W. Whitehouse of the University of Queensland, and Mr. W. D. Francis, Assistant Government Botanist of Queensland.

II. Previous Literature on the Area.

The first reference to the area is that of W. H. Rands,[1] who in 1890 wrote: " . . . At Gigoomgan a great mass of bluish-grey limestone can be traced for a distance of at least 14 miles, running in a north-north-westerly direction. Near the head station I found a few fossils, but they are very scarce, and not well preserved; I was able to identify some as identical with those of the Gympie beds; they were *Aviculopecten squamuliferus* Morris, *Spirifer* sp., *Stenopora* sp., and *Encrinital* stems."

L. C. Ball [2] visited Gigoomgan Head Station in 1903, where he obtained "specimens of the impure fossiliferous limestones outcropping in the neighbourhood". "On being sectioned the rock was found to contain foraminifera similar to those of Pokolbin limestones of the Hunter Valley in New South Wales. They have yet to be determined and described."

In the following year the same author stated: "There are in the neighbourhood of Gigoomgan Head Station large outcrops of limestone of all degrees of purity, from marble to calcareous shale." [3]

B. Dunstan [4] in 1914, after referring to the "enormous deposits of limestone" at Gigoomgan, correlated them with other deposits as follows: "These [Gigoomgan] limestone deposits are a south-easterly continuation of the Biggenden deposit, and form portion of a great belt extending south-easterly to Gympie. This belt, it may be observed, occurs near Traveston, a railway station on the North Coast Line, and from there can be traced almost continuously in a north-westerly direction . . . to Rosedale, a railway station to the north-west of Bundaberg, the belt being over 100 miles in length."

III. Field Description.

The mass of limestone which forms the subject of this paper appears to form part of a somewhat regular although discontinuous belt. To what extent the material of this belt, beyond the development at Gigoomgan itself, is or may have been algal, the authors have no knowledge. The southerly extension of the Gigoomgan occurrence has been so altered by thermal metamorphism that there is no clue to its original nature, but those northern outcrops which the authors have inspected on the supposed extension towards Biggenden are certainly not algal. Nevertheless, as the algal nature is not recognizable in hand specimens, it may be that algal limestones do form quite a large proportion of those outcrops of the belt that have not been inspected with this possibility in view. The extent of the Gigoomgan occurrence must therefore be regarded merely as an ascertained minimum so far as the distribution of the algae is concerned.

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[1] *Queensland Geological Survey Publication*, No. 59, 1890, 1.

[2] *Queensland Government Mining Journal*, iv, 1903, 298.

[3] *Queensland Geological Survey Publication*, No. 194, 1904, 52.

[4] *Queensland Government Mining Journal*, xv, 1914, 356.

The limestone examined for the presence of algae extends as an irregularly lenticular mass in a north-north-westerly direction for approximately 4 miles, its greatest width being a little under 1 mile. Although, for the most part, it is exceedingly difficult to make a confident determination of strike or dip, the weight of the evidence points to a strike between north and north-north-west and a dip which varies from vertical to 40° and which is normally to the west.

Owing to the discontinuity of outcrops, no complete sequence can be obtained in any one section, and although several partial sections were traversed it is inadvisable to combine these into one composite section, owing to the probable lenticularity of the beds. Nevertheless, it can be stated with considerable confidence that the beds group themselves roughly in descending order as follows :—

1. Algal limestone.
2. Calcareous shales and fossiliferous limestones containing corals, brachiopods, etc.
3. Limestones sometimes algal and sometimes siliceous with numerous sponge spicules.

A more detailed examination of the northerly part of the development in Portion 8, Parish of Gigoomgan, gave the following sequence of outcrops as traced across the strike from west to east :—

0– 500 yd.	Algal limestone tolerably uniform in character as shown by microscopic examination of 28 uniformly spaced samples and containing practically no other fossils than occasional fragments of large lamellibranch shells scattered throughout the mass. From 300 to 500 yards there are a few thin bands containing fossil corals, brachiopods, etc.
500– 700 yd.	Principally shales.
700– 750 yd.	Algal limestone.
750– 950 yd.	Algal limestone alternating with marine fossil bands.
950–1200 yd.	Variable limestone in part algal, with marine fossil bands, and in part siliceous with numerous sponge spicules.

Based on the very conservative estimate of an average dip of 45° the main mass, composed essentially of algal remains, measures approximately 1,100 feet in stratigraphical thickness, while the ascertained stratigraphical range of the algal limestones is considerably more than twice as great.

IV. DESCRIPTION.

The algal limestone as typically developed is a uniformly fine-grained dark grey rock, fetid when struck, and showing no trace of any organic structure to the naked eye, except occasional fragments of lamellibranch shells. Irregular veins of siliceous (chalcedonic) material are fairly common and stand out conspicuously on the surface of the more deeply weathered outcrops. Under the microscope the rock is seen to be made up almost entirely of finely crystalline calcite with, sparsely distributed through the rock, small granules of iron pyrites often finely interlaced with the algal remains, while occasional minute angular fragments of quartz are met with. Certain portions show staining due to the presence of limonite, but mineralogically the rock is essentially an aggregate of crystals of calcite. There is a close relationship between the crystalline structure and the organic structure of the rock due to the fact that each algal rod is usually made up of a single elongate crystal of calcite, the organic boundary thus coinciding with the crystal boundary. Further, the orientation of the crystal of calcite is in nearly all cases so arranged that extinction takes place when the length of the rod is parallel to one of the cross wires. In addition to this the cleavage lines and twinning lamellae which appear as oblique lines across the rods are terminated by the sides of the rods. All these factors result in emphasizing the individuality of each of the rods with the result that the algal structures are almost as conspicuous under crossed nicols as with ordinary light. Under reflected light the dull white porcellanous character so typical of the calcareous algae is evident.

No signs of dolomitization are present in any of the slides examined and this is in keeping with the chemical composition of the rock as determined by analysis.

A large number of small specimens collected indiscriminately over the whole area occupied by the algal limestone gave the following mean chemical analysis, which, on its lime content, would give a calcite percentage of approximately 83%.

	%
SiO_2	12·44
Al_2O_3	2·77
Fe_2O_3	0·65
CaO	46·44
MgO	trace
S	0·30
Loss on ignition	37·04
	99·64[1]

The algal remains, for the most part, consist of a confused mass of rods giving elongate rectangular longitudinal sections and rounded (sometimes polygonal) cross sections. The rods are brownish in colour and of a dusty appearance due to the presence of numerous minute bodies. Under high magnification this appearance is resolved into a granular, or serpentinous granular structure.

The rods are comparatively uniform in size, one set of measurements (micro slide 525[2]) showing an average length of 0·20 mm.

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[1] Analysis by courtesy of Queensland Cement and Lime Company, Limited.

[2] University of Queensland Rock Slide Collection.

and an average width of 0·05 mm. In cross section the average diameter appears to be 0·06 mm. The last value probably represents the true average thickness of the rods. Where a slide shows numerous cross sections side by side they are usually closely appressed and have polygonal outlines, whereas isolated cross sections are roughly circular or elliptical. The great majority of the rods are straight and constitute an intricate interlocking felt-like mass. In some cases a sub-parallel arrangement can be detected and this usually corresponds with the bedding of the rock as determined in hand specimens. Organic structures are found only after diligent search, although it is not difficult—indeed all too easy—to read into the confused mass structures that maturer considerations prove quite fortuitous arrangements of the rods. But apart from such pseudo-structures and other doubtful cases there are several simple structures that are found so frequently that they can scarcely be accidental. Of these the commonest is a V-shaped fork formed by the union of two rods. Sometimes a small but stout bud-like structure is seen, within the narrowest part, at the junction. Another structure less common is a Y-shaped arrangement in which the supporting part is a rod somewhat thicker than either of those it supports. The upper part of the structure can be readily correlated with the V structure mentioned above. A third structure consists of unusually thick rods which are split at one end into two portions of approximately equal diameter closely appressed.

Certain more complex structures have also been observed, but these are by no means common. Some of these are illustrated in Plates XVII–XX. Digitate growths of several rods from a common base occur in several microslides, while other sections suggest branches arranged spirally about an axis (see Plate XX).

Several of the larger structures possess a homogeneity of appearance and uniformity of arrangement together with an increase in the number of rods from the base upwards which suggests that they represent more or less complete "colonies" if such a word may be used in this connection. These show in some cases dichotomy of the individual branches like that of the simple Y structures described above.

Piecing together this fragmentary evidence the authors tentatively conclude that the algae grew in some cases by simple dichotomy forming colonial aggregates that range from loosely fasciculate to solidly massive structures with, between these extremes, plumose structures of varying degrees of compactness. In other cases colonies seem to be formed by spiral growth about an axis.

The general absence of curved rods suggests a comparatively rigid and brittle character for the original algae suggestive of the "lithakophytes" of Setchell.[1]

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[1] *University of California Publications in Botany*, xii, No. 89, 1926, 310.

On the evidence before them the authors do not feel competent to express a definite opinion as to the algae present. They are unable to reconcile them with the description of any species of fossil alga known to them. The closest generic parallel to the prevailing form appears to be with *Mitcheldeania*, a conclusion that is supported by Mr. F. Chapman, to whom specimens and micro-slides were submitted and who has kindly provided the following notes on the algae :—

" There are three kinds of algae present. The most abundant is a filamentous and fasciculated form, somewhat resembling *Mitcheldeania*, but may be an allied genus. It seems to differ from that form in having no mural pores, as shown by Nicholson in *M. gregaria*.

" There is very little doubt that these abundant and fasciculated masses belong to the Cyanophyceae (Blue Green Algae). Their abundant growth may be due to the influence of warm water and even thermal springs prevailing in the locality at the time.

" The diameter of the tubes or filaments of the present form coincides with that of *Mitcheldeania gregaria*. The genotype of that genus, by Wethered, is rather obscure in its chief features, but appears to be of concentric structure. The Queensland form does not seem to belong to *Solenopora*, for its fundamental characters lack the parallel and finely cellular growth so distinctive of that genus and *Lithothamnion*, both related to the Rhodospermeae.

" Slide 523 shows adherent growths of cf. *Aphralysia*. Also cf. *Mitcheldeania* (with ferruginous outlines). There is also present a lamellibranch shell with a boring fungus, cf. *Achlyites*, having hyphal tubes with occasional sporangia.

" Slide 519. Similar to 520, but a thicker section.

" Slide 520. A good section cf. *Mitcheldeania* sp. nov. Differing from *M. gregaria* in having rounded tubes, in cross section, and with a more closely packed and less radiate mode of growth. Thin walls without ? mural pores of *M. gregaria*. Diameter of tubes, ·057 mm.—about equal to that of *M. gregaria* Nich., but twice as large as *M. nicholsoni*."

V. AGE AND FOSSIL CONTENT OF THE LIMESTONE.

It is fortunate that although the algae themselves provide no clue as to the age of the limestone, the other fossils present in the occasional bands show that the mass is of late Palaeozoic age.

Dr. F. W. Whitehouse to whom the fossils were submitted has kindly provided the following list of identifications and comments :—

" 1. From near the Homestead, Gigoomgan.

Plerophyllum cf. *gregoriana* de Kon.
Plerophyllum sp.
Linoproductus farleyensis (Eth. fil. et Dun)
Anidanthus sp.

Productus or *Strophalosia* sp. ind.
Spirifer sp. ind.
Neospirifer (?) *tasmaniensis* (Morr.) auct.
Martiniopsis morrisi Eth. fil.
Martiniopsis sp. ind.
Mourlonia (?) sp. ind.
Conularia cf. *inornata* Dana.

"2. From Portion 8, Parish of Gigoomgan.
Favosites (?) sp. nov.
Plerophyllum cf. *gregoriana* de Kon.
Plerophyllum sp. (? nov.).
Crinoid ossicles.
Undetermined bryozoa.
Anidanthus sp.
Linoproductus farleyensis (Eth. fil. et Dun)
Spirifer sp.
Pleurotomaria sp. juv.

"3. From Portion 6, Parish of Gigoomgan.
Trachypora wilkinsoni Eth. fil.
Plerophyllum sp. ind.
Anidanthus (?) sp.
Productus or *Strophalosia* sp. ind.
Spirifer sp. ind.
Neospirifer sp. nov.

"This is a typical fauna of the Eastern Australian 'Permo-Carboniferous' sequence, representing a stage that I believe to belong to the upper part of the Upper Carboniferous."

To Dr. Whitehouse's list should be added of course the calcareous algae that form the subject of this paper and the micro-fauna associated with the algae. The latter is very sparsely represented, the least rare fossils being siliceous sponge spicules which are found especially in the lowest part of the algal limestone. Even rarer, but perhaps of more interest, are certain minute fossils, one of which Sir Edgeworth David has suggested probably represents the proximal end of a foraminifer closely allied to, if not specifically identical with, *Nodosaria permiana* Spandel which occurs in the Permo-Carboniferous beds of New South Wales.

VI. SIGNIFICANCE OF THE DEPOSIT.

The features of outstanding interest in the Gigoomgan limestone are :—

1. The great size of the mass.
2. The purely algal character and uniformity.
3. The absence of dolomitization.
4. The absence of associated oolites.

With regard to the first and second points, the authors have sought in vain for a closely parallel case in the published records of algal limestones. In nearly every case where great masses of limestone have been referred to algae, there is lack of agreement as to their origin, while in those cases where undoubted "algal limestones" are described the algal colonies are not sufficiently numerous to constitute the rock mass in its entirety.

When we turn to algal banks and reefs forming at the present day, closely analogous conditions both as to extent and purity of the algal mass may be found although they are by no means common.

But although the importance of algae as reef builders at the present time now meets with general recognition largely as a result of the efforts of Stanley Gardiner, Finckh, Howe, and Setchell, there is, so far as the authors are aware, no description of a large mass of limestone made up entirely or almost entirely of fossil algal remains.

The following references have been selected from accounts of limestones which appear to resemble the Gigoomgan limestone in certain features.

With regard to the supposedly algal limestones of Algonkian age described by Walcott [1] the following quotations are to the point: "The purer non-algal limestones are of considerable vertical thickness and their distribution indicates bodies of water several thousand square miles in area. The banks or reefs of algal deposits make a small percentage of the total mass of limestone . . . " "The Newland limestone of the Belt Series is about 2,000 feet (630 m.) in thickness and the algal forms are reported by Collen as occurring in it from base to summit . . . " " . . . the algal forms extend through several thousand feet of strata . . . . they are so abundant as to form reefs or banks of fossil algae in the section."

Blackwelder [2] has described "A Fully Exposed Reef of Calcareous Algae (?) in the Middle Cambrian of the Teton Mountains", which occurred about 400 feet below the base of the Bighorn dolomite, but this reef was "but 7 feet thick". In another publication [3] the same author has described the very extensive Bighorn Dolomite of Wyoming which ranges from 100 to 300 feet in thickness and which contains "massive banks" of "vast extent" which he suggests are largely made up of the fossil remains of calcareous algae. He admits, however, that there is some doubt as to whether the structures are even organic.

Moore [4] has noted from the Pre-Cambrian of Belcher Islands, Hudson Bay, "a remarkable band of concretionary limestone over 400 feet thick and consisting of spherical to sub-spherical balls varying from about an inch to 15 inches in diameter." These he regards as algal concretions similar to those now found in lakes and streams.

Mawson and Madigan [5] have described from the Pre-Ordovician rocks of Central Australia a series of limestones 1,330 feet thick

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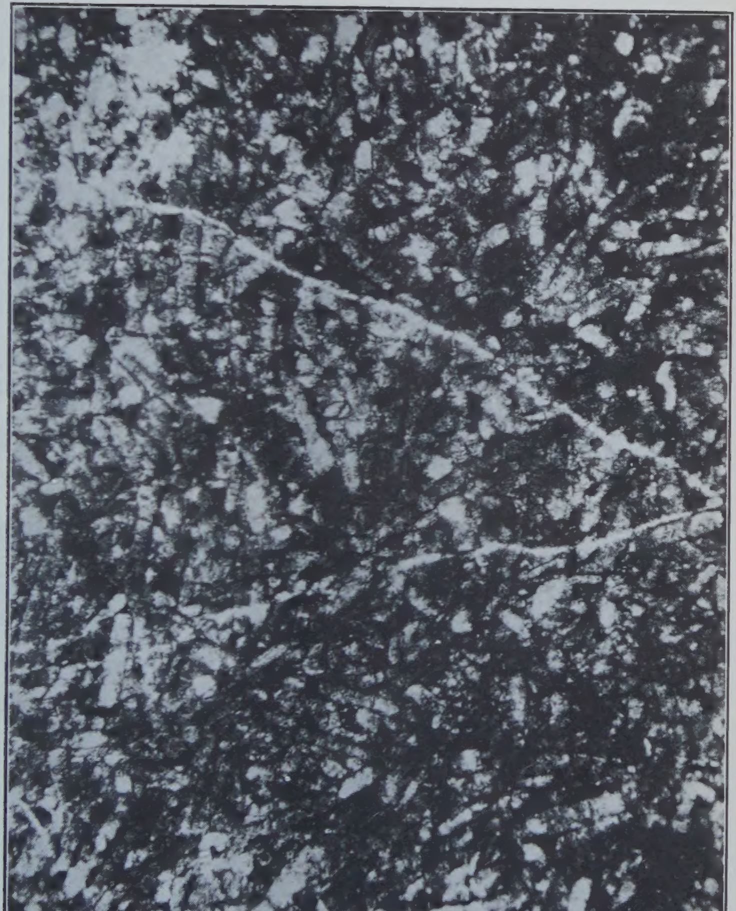
[1] *Smithsonian Miscellaneous Collections*, lxiv, No. 2, 94 and 99.

[2] *American Journal of Science*, Fourth Series, xxx, 1915, 646.

[3] *Bulletin of the Geological Society of America*, xxiv, 1913, 607–24.

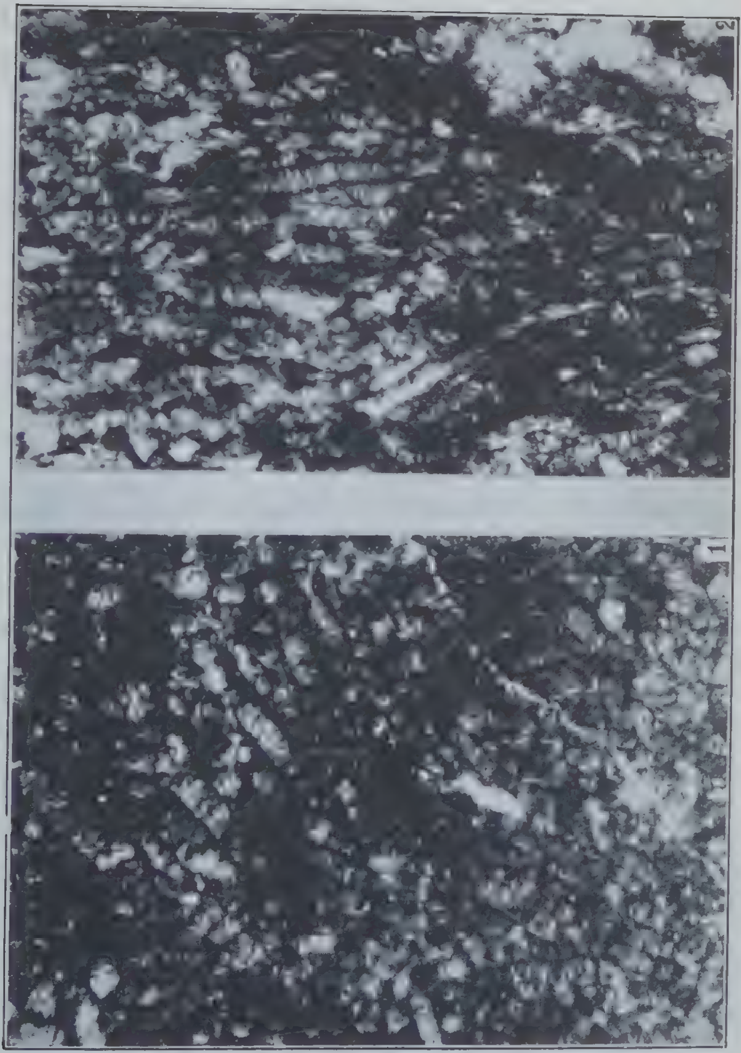
[4] *Bulletin of the Geological Society of America*, xxix, 1917, 128.

[5] *Quarterly Journal of the Geological Society*, lxxxvi, 1930, 422.

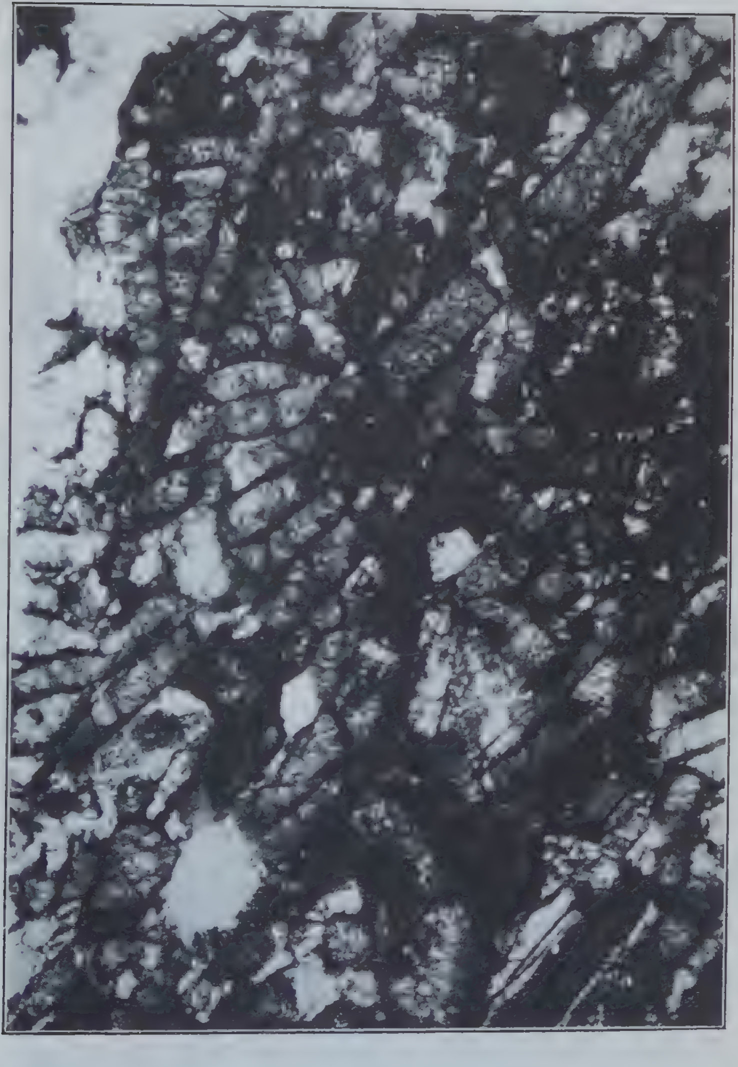


ALGAL LIMESTONE FROM GIGOOMGAN, QUEENSLAND.

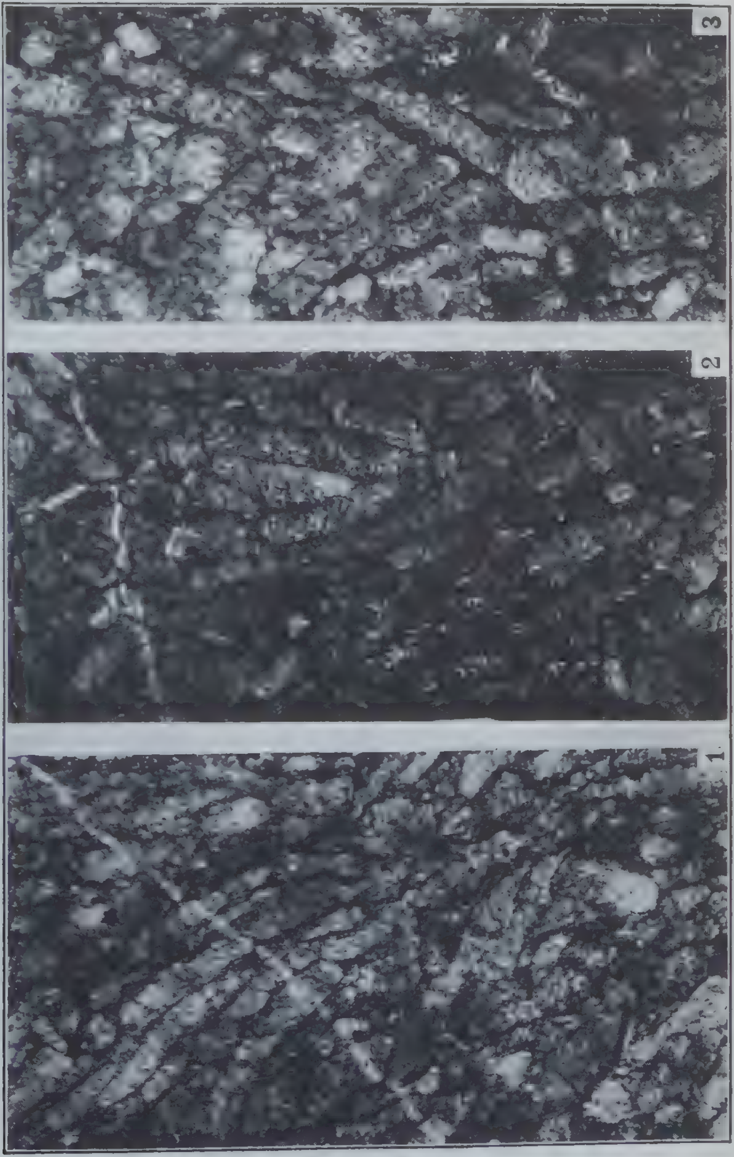
[*To face p.* 296.



Algal Limestone from Gigoomgan, Queensland.



Algal Limestone from Gigoomgan, Queensland.



Algal Limestone from Gigoomgan, Queensland.

some of which "appear to be moderately dolomitic" and exhibiting "an extraordinary development of fossil algae of several varieties". "Much of the limestone is solidly made up of the remains of these algae. They evidently flourished in dense masses, growing in shallow waters. The living growth was analogous to the coral-reef formations of later times."

Unfortunately in all of these cases some doubt exists as to whether the structures described are in fact algal. Thus with regard to the concretionary structures described as algae by Walcott, Seward [1] wrote "I fail to see that the American specimens have any claim to be regarded as algae, and I venture to think that they afford no real evidence of the co-operation of plants in their formation".

Again Garwood [2] in discussing the algae described by Mawson and Madigan from Central Australia said he "would be sceptical of the algal nature of some of the specimens, until he had seen sections of them", and added "one must not admit concretionary limestones as algal, unless they showed algal structure".

The necessity for such scepticism seems warranted by the fact that Holtedahl [3] and others have described structures believed to be inorganic which are indistinguishable in their essential features from the supposed calcareous algae of the Pre-Cambrian reef-like masses.

But apart from such dubious occurrences there are many cases on record of undoubted fossil algae in Palaeozoic and later formations.

Seward [4] as early as 1894 summarized the then available evidence of algae as rock-building organisms, but it is chiefly to the enthusiasm of Garwood over a long term of years that geologists are indebted for their knowledge of the subject. The latter author [5] published in 1913 in tabular form the important algal horizons throughout the world, showing that these ranged from Antarctica to the Baltic provinces and extended from the Cambrian period to the Newer Tertiary.

In his recent presidential address to the Geological Society of London, Professor E. J. Garwood has recorded many important additions to our knowledge of the fossil calcareous algae since 1913.[6]

But, although the term "algal limestone" has been applied to many of these, in no case are the algae sufficiently numerous to constitute the rock mass in its entirety.

Turning to the present day we see that calcareous algae play their most important part as reef builders in association with corals, a point emphasized by Stanley Gardiner,[7] but there are also on record both from tropical and arctic seas great banks composed almost solely of calcareous algae. Howe[1] in a paper emphasizing the part played by algae as "coral-reef" builders cites Mme. A. Weber van Bosse's description of a whole reef near Timor consisting chiefly of *Lithothamnion*, and Kjellman's statement that off the coasts of Spitsbergen and Nova Zembla *Lithothamnion glaciale* "covers the bottom in deep layers for several miles" so that "in the formation of future strata of the earth's crust in these regions it must become of essential importance". Howe also cites Foslie's statement that "north of the polar circle on the coast of Norway banks have been met with which cover the bottom for several miles and plants appear in immense masses, frequently representing only one species".

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[1] *Ibid.*, lxxix, 1923, lxxvi.
[2] *Ibid.*, lxxxvi, 1930, 429.
[3] *American Journal of Science*, i (CCI), 1921, 195.
[4] *Science Progress*, ii, 1894, 10–26.
[5] GEOL. MAG., 1913, 553.
[6] *Quart. Jour. Geol. Soc.*, lxxxvii, Part 3, Aug., 1931, lxxiv–c.
[7] *Proc. Camb. Philos. Soc.*, ix, 1898, 477.

Again, when referring to the West Indies, Howe writes of "banks and reefs that appear to consist almost wholly of calcareous plants".

Setchell[2] in bringing up to date Howe's summary of the situation quotes Foslie's statement that "the *Challenger* expedition met with a bank off Tahiti which had probably been formed by a single species, *Lithothamnion dickiei*".

Thus pure stands of calcareous algae are found not only in arctic waters where they are free from the competition of corals but in tropical waters where, although their growth may be more vigorous, they enjoy no such immunity. It may be that in times such as the Pre-Cambrian, early Palaeozoic, or Permo-Carboniferous, when reef-building corals were comparatively rare, the formation of purely algal banks or reefs would be rendered more probable than in either middle Palaeozoic or post-Palaeozoic times when the reef-building corals flourished.

The absence both of oolitic structure and of magnesia from the Gigoomgan algal limestone is a matter of some surprise in view of Garwood's[3] generalization anent "the constant association of fossil calcareous algae with oolitic structure and also with dolomite".

With regard to the former, Garwood points out that Wethered has shown that an intimate association frequently exists between *Girvanella* tubes and oolitic structures and Garwood himself notes the association of oolites with *Solenopora* in the Lower Cambrian of Antarctica and in various parts of Europe from the Ordovician period to the Jurassic. In view of the general association of algae and oolites over such a wide spatial and temporal range the absence of oolites from Gigoomgan is especially noteworthy.

With regard to the question of magnesia content Garwood[4] writes "The presence of dolomites in connection with algal growths at different geological horizons appears to show that the beds have accumulated under definite physiographical conditions similar to those which obtain to-day in the neighbourhood of coral reefs ".

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[1] *Science*, New Series, xxxv, 1912, 840.

[2] Op. cit., 313.

[3] GEOL. MAG., 1913, 552.

[4] Op. cit.

In a detailed account of the origin and structure of one of the Cook Islands, Marshall [1] wrote " From a study of the composition of the Mangaian limestone, it appears that the only material in which magnesium carbonate is present in important amounts is that of the *Lithothamnion* ridge ". Later in the paper the same author suggested that the conditions of the *Lithothamnion* ridge in coral reefs of the present day appear to approximate more closely those under which dolomitic limestones have been formed than does any other set of conditions at present known.

With regard to the calcareous algae of the present day Clarke and Wheeler [2] point out that they fall into two groups. " One of these, of which *Lithothamnium* is the most familiar example, is highly magnesian ; the other, represented by *Halimeda*, is almost free from magnesia." The same authors as the result of the comparison of analyses from many parts of the world suggest that the proportion of magnesia in the algae is influenced by temperature, the algae from the warm parts of the world being more magnesian than those from arctic regions.

The same authors point out that with the algae, as with many other organisms, those in which the skeletons are aragonitic are almost non-magnesian. The Gigoomgan limestones are completely calcitic not aragonitic, but this does not mean that they were necessarily calcitic at the time of origin as it is very improbable that the relatively unstable aragonite would, if formed, have persisted as such from late Palaeozoic times to the present day.

Skeats [3] holds that dolomitization of limestones is a process that takes place in shallow waters, but that since it is probably slow some calcareous reefs might subside at a sufficiently rapid rate, through the favourable zone to prevent dolomitization.

It is of interest to note that as a result of the chemical examination of material from the bore put down by the Great Barrier Reef Committee [4] at Michaelmas Cay, the magnesia content in a series of forty samples ranging from 12 to 600 feet in depth reached a maximum of 2·4% at a depth between 405 and 441 feet. The average value of MgO throughout the entire range was only one-half of one per cent.

It would seem that the nature and origin of dolomitization is still a debatable question and this conclusion is supported by Wallace's [5] recent summary of the position.

With reference to the possible climatic significance of the

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[1] *Bernice P. Bishop Museum Bulletin* 36, 1927, 30.

[2] *United States Geological Survey, Prof. Paper.*

[3] *American Journal of Science*, Fourth Series, xlv, 1918, 199.

[4] Information supplied by courtesy of Great Barrier Reef Committee.

[5] *Researches in Sedimentation*, National Research Council, Washington, 1927, 64.

Gigoomgan occurrence the general impression is that algal reefs are indicative of tropical or sub-tropical conditions.

Thus Glock,[1] who has made a special study of the subject, concludes that " The most significant point in regard to the algae lies in the fact that lime-secreting forms become most numerous in the sub-tropical and tropical regions, attain their greatest development there, and appear to perform their most important work in the warmer waters ". Seward [2] however, sounds a warning note : " The abundance of the genus *Lithothamnion* in the North Polar sea, where the temperature rarely rises above 0° C., is a fact to be reckoned with when use is made of calcareous algae as a measure of climate."

VII. SUMMARY AND CONCLUSIONS.

The above account appears to be the first record of fossil algae in Queensland. Although algae have been described from early Palaeozoic rocks in other parts of the Commonwealth they have not hitherto been recorded from late Palaeozoic strata anywhere in Australia.

At Gigoomgan in Queensland a great mass of limestone several miles in length and at least eleven hundred feet thick is made up almost entirely of algal remains.

Although similar in some respects to species of *Mitcheldeania* as described originally by Wethered [3] and later by Garwood [4] the alga making up the bulk of the mass appears to be new to science. It seems reasonable to conclude from the evidence submitted that in late Palaeozoic times calcareous algae were capable of existing in pure stands of such large dimensions as to produce very extensive reef masses.

The comparatively poor development of reef-building corals at this time, as compared with the present day, may have been an important negative factor contributing towards the purity of the algal reef, although pure stands of *Lithothamnion* are known to occur at the present day.

In view of the unfossiliferous appearance of the Gigoomgan limestone in the hand specimen, the authors suspect that similar algal limestones in other parts of the world might very easily have been overlooked. The alternative is that the Gigoomgan algal reef represents a very rare development.

The evidence provided by the distribution of calcareous algae at the present day is so conflicting that the authors think no good purpose would be served by an attempt to interpret the climatic significance (if any) of the Gigoomgan deposit.

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[1] *American Journal of Science*, Fifth Series, vi, 1923, 406.

[2] *Quart. Jour. Geol. Soc.*, lxxix, 1923, lxxiv.

[3] GEOL MAG., 1886, 535, Pl. XIV, Fig 6.

[4] GEOL. MAG., 1913, 445.

For the same reason the authors have resisted the temptation to erect interesting hypotheses on each of the several unusual features associated with the deposit and have contented themselves with placing on record the facts of observation.

VIII. BIBLIOGRAPHY OF AUSTRALIAN FOSSIL ALGAE.

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EXPLANATION OF PLATES XVII–XX.

All plates are microphotographs of thin sections taken with ordinary transmitted light.

PLATE XVII.

Microphotograph showing abundance and arrangement of algal rods composing almost the entire mass of compact limestone more than 1,000 feet thick (× 55).

PLATE XVIII.

FIG. 1.—Microphotograph showing one type of algal growth (× 85).
,, 2.—Microphotograph showing a somewhat similar mode of growth (× 80).

PLATE XIX.

Microphotograph showing a distinct arrangement of the algal remains (× 130).

PLATE XX.

FIGS. 1, 2, and 3.—Microphotographs showing digitate and spiral growths (× 125).

Larger Foraminifera from the Eocene of Santa Elena Peninsula, Ecuador.

By R. Wright Barker, B.A., F.G.S.

(PLATES XXI and XXII.)

THE present paper gives a general account of the larger foraminifera from the Santa Elena Peninsula in south-west Ecuador, with descriptions of three new species. All the material except that from the Guayaquil Limestone was obtained from the concessions of the Anglo-Ecuadorian Oilfields, Limited, to whom my thanks are due for permission to publish these results.

Dr. George Sheppard (*Bull. Amer. Assoc. Petrol. Geol.*, xiv, 1930, 276) gives the following sequence of the beds outcropping in this area :—

F.	Ancon Point Series	Lower Oligocene.
E.	Seca Series	Upper Eocene.
D.	Socorro Series	
C.	Clay Pebble Bed	
B.	Middle Grits	Middle Eocene.
A.	Guayaquil Limestone	Lower Eocene.

It is proposed to consider the formations A–D in turn, and give a brief account of the large foraminifera recorded from them.

A. *The Guayaquil Limestone.*

The Guayaquil Limestone is a light-coloured, fine-grained limestone which forms a westward-dipping escarpment in the neighbourhood of Chongon, a town to the west of Guayaquil. Dr. J. Wolf in 1892 declared the formation to be Cretaceous in age, but recently specimens were sent to Dr. Wayland Vaughan, who reported (in Sheppard, op. cit., p. 281) the presence of " a small lenticular species of *Discocyclina* . . . very close to *D. cubensis* Cushman ", and declared the rock to be of undoubted Eocene age, and probably Upper Eocene. An examination of several thin sections of the limestone from Guayaquil revealed no foraminifera so thick as *D. cubensis* Cushman, in which the ratio of diameter to thickness is given as 2 : 1.

On the other hand, several sections were obtained in which the ratio was 4–5 : 1. The specimens were 2·3–3 mm. in diameter, and were lenticular in shape, the median layer increasing from 23μ in thickness at the centre to 46μ at the periphery, the roof of the layer being 23μ in thickness (Pl. XXII, Fig. 1).

The nearest approach to this is *Discocyclina weaveri* var. *parvipapillata* Vaughan, described by Dr. Wayland Vaughan in 1929 from the Lower Eocene of Mexico (*Proc. U.S. Nat. Mus.*, lxxvi, 1929, art. 3, pp. 7, 8, pl. i, figs. 3, 4, 4*a*). In this species the diameter is 2·75–3·2 mm., the thickness 0·5–0·8 mm. (ratio app. 5 : 1), and the median layer increases in thickness from 25μ at the centre to 40μ

at the periphery, the section measuring under 3·0 mm. in diameter. Where the median layer was exposed in horizontal section in the slides of Guayaquil Limestone the chambers were found to be approximately 40μ (radial) $\times$ 20μ transverse, as compared with $50\mu \times 25$–40μ; in both species the chamber walls in adjacent annuli alternate in arrangement as a general rule. The nucleoconch was not exposed in horizontal section in the Guayaquil specimens, but in vertical section was seen to be bicellular, measuring 230μ in length in two specimens and 115μ and 138μ respectively in height. The lateral chambers were in tiers of 10–12 above the nucleoconch, but were not very clearly shown owing to the crystallization of the specimens. These agree internally with *D. weaveri* var. *parvipapillata*, but since the external ornamentation is not known it is preferable not to identify it.

On the same slides were seen several smaller foraminifera and well-developed hypothallia of *Archaeolithothamnium* (shown in Pl. XXII, Fig. 4).

Material.—Sections C. 382–C. 385.

B. *Middle Grits.*

This series of fine- to medium-grained quartz grits is not exposed at the surface in the Santa Elena Peninsula, but is shown by borings to contain very few fossils, the principal forms being two somewhat similar species of *Discocyclina*. These are new species, and are both of very small size.

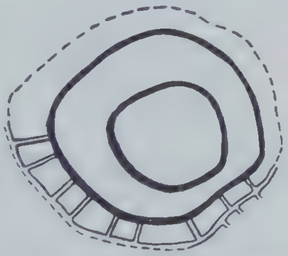

FIG. 1.—*Discocyclina anconensis* sp. nov. Nucleoconch × 100 approx. (C. 397).

Genus DISCOCYCLINA Gümbel, 1868.

Discocyclina anconensis sp. nov. (Pl. XXI, Figs. 1, 4.)

The specimens of both this and the following species were obtained from well samples, and were very badly preserved. It is therefore impossible to determine the nature of the external ornament and the presence or absence of a flange.

The diameter varies from 2·0–2·1 mm., with an average thickness of 1·0 mm. Vertical cross sections are lenticular, the edge of the test always being in a damaged condition.

The embryonic apparatus consists of a large cell, circular in horizontal section, entirely surrounding an initial spherical chamber. The internal diameter of the initial chamber in four typical sections varied from 140μ to 170μ, the second surrounding chamber in the same sections measuring from 280μ to 315μ in diameter.

The median chamberlets are rectangular and are arranged in annuli, which tend to be wavy and slightly irregular in outline. The cells occasionally attain dimensions of 70μ × 18μ near the periphery, with walls 7–10μ in thickness, although they more commonly measure only 30μ × 18μ.

A vertical section shows the presence of numerous pillars which attain a thickness of 80μ at the surface. The median layer is seen to increase in thickness gradually from 35μ near the embryo to 70μ near the periphery. The horizontal sections appear to show the development of the interseptal canals described by Schenck (*Trans. San. Diego Soc. Nat. Hist.*, v, 1929, 216–20).

The only other species of *Discocyclina* which show an embryo in which the initial chamber is entirely surrounded by the second chamber appear to be *D. archiaci* (Schlumberger), *D. marthae* (Schlumberger), and *D. californica* Schenck. (For relationships, see table, p. 306).

Holotype.—C. 387. *Paratypes.*—C. 386, C. 388–C. 391, C. 397*a*, 398*a–d*, C. 399 *pars*.

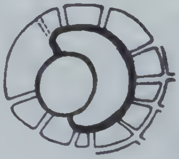

FIG. 2.—*Discocyclina sheppardi* sp. nov. Nucleoconch × 100 approx. (C. 397).

Discocyclina sheppardi sp. nov. (Pl. XXI, Fig. 2.)

A number of specimens of this species were obtained in association with *D. anconensis* sp. nov. in the Middle Grit Series. The specimens have a diameter of from 1·4 mm. to 3 mm., the latter measurement indicating the average for the most perfectly preserved specimens. The specimens show an average thickness of 0·7 mm., thus giving a ratio of diameter to thickness of 4 : 1 app. The ornament was not visible.

The embryonic apparatus (Text-fig. 2) is bicellular and nephrolepidine in shape, consisting of a spherical initial chamber 120μ in diameter (average), partly embraced by a reniform chamber with an average greater diameter of 175μ. The walls of the apparatus have a thickness of 7–14μ.

The median chambers are rectangular, some specimens showing a greater transverse than radial diameter, the majority measuring $20\text{–}30\mu \times 15\text{–}17\mu$, the radial diameter being the greater. They are arranged as a general rule in regularly spaced circular annuli, though in one section there are a number of exceptionally elongate cells near the periphery measuring $60 \times 18\mu$.

The walls are well developed, that of the outer embryonic chamber being 10μ in thickness, and those of the median chambers 14μ. A vertical section shows that the median layer increases in thickness from 40μ near the centre to 55μ at the periphery, the measurement being taken between the roof and floor of the layer. Pillars are only very slightly developed, and the lateral chambers are very obscure and cannot be seen clearly.

This species shows no marked relationships with previously described species, and hence it possesses little value in correlating the Grits with other Tertiary deposits of south or central America. It may be said to belong to the same group as *D. psila* Woodring and *D. peruviana* (Cushman), but it is quite distinct from either of these two species (see Table, p. 306).

Holotype.—C. 392. *Paratypes.*—C. 393–C. 396, C. 397*b*, *c*, 398*e*–*f*, C. 399 *pars.*

Horizon.—The size of the two Discocyclines described above and apparent relationships with *D. weaveri* Vaughan and *D. psila* Woodring tend to confirm the idea that the Middle Grits are of Middle Eocene Age. Elsewhere in S. America *Discocyclina* in beds of Upper Eocene age is associated with stellate forms of the same genus and species of *Isolepidina*, both of which appear to be absent from the Middle Grits, but which occur in the Socorro Series at a considerably higher horizon.

C. *The Clay Pebble Bed.*

I am indebted to Dr. T. Wayland Vaughan for permission to give the following unpublished records of foraminifera in the Clay Pebble Bed :—

Operculina ocalana Cushman.
Operculina floridensis (Heilprin) Cushman.
Operculinella willcoxii var. nov.
Lepidocyclina sp. nov. (A and B forms).
Gypsina sp. cf. *globulus* Reuss.

D. *Socorro Series.*

A lens of coarse grit on the sea coast near Ancon, which is believed to be near the top of the Socorro Series, yielded an interesting fauna, including the following forms :—

Actinocyclina cf. *asteriscus* (Guppy), *Polylepidina* C. 409 sp., *Helicolepidina polygyralis* sp. nov., and *Operculina ocalana* Cushman C. 410–411.

TABLE SHOWING RELATIONSHIPS OF *Discocyclina anconensis* SP. NOV. AND *Discocyclina sheppardi* SP. NOV.

Character.	*Discocyclina anconensis* sp. nov.	*Discocyclina archiaci* (Schlumberger).[1]	*Discocyclina marthae* (Schlumberger).[2]	*Discocyclina californica* Schenck.[3]	*Discocyclina sheppardi* sp. nov.	*Discocyclina psila* Woodring.[4]	*Discocyclina peruviana* (Cushman).[5]
Diameter	2·0–2·1 mm.	Up to 20·0 mm.	2·3–7·0 mm.	3·5–8·5 mm.	1·4–3·0 mm.	1·2–4·7 mm.	6 mm.
Thickness	1·0 mm.	2·0 mm.	1·0 mm.	2·5–5·0 mm.	0·7 mm.	0·5–0·7 mm.	1·5–2 mm.
Diameter of initial embryonic chamber	140–170μ	*250μ	220μ	†210μ	120μ	80–95μ	105μ
Diameter of second embryonic chamber	280–315μ	*400μ	390μ	350μ	175μ	160–170μ	245μ
Thickness of equatorial layer : (*a*) at the centre . .	35μ	—	30–40μ	—	40μ	11μ	—
(*b*) at the periphery . .	70μ	—	80–90μ	—	55μ	23μ	—

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[1] C. Schlumberger, 1903, *Bull. Soc. géol. France*, **4,** iii, 277, fig. C, and pl. viii, figs. 5–7, 11. * Measurements from fig. C, p. 277.

[2] Measurements from figures, C. Schlumberger, 1903, *Bull. Soc. géol. France* **4,** iii, 284, pl. 10, figs. 27, 29, 32.

[3] H. G. Schenck, 1929, *Trans. San Diego Soc. Nat. Hist.*, v, 14, 225, 226, figs. 8, 9, 10. † Measurements from Fig. 9, p. 223.

[4] W. P. Woodring, 1930, *Trans. San Diego Soc. Nat. Hist.*, vi, 4, 149, 150, pl. xv, figs. 1–4.

[5] Original description by Cushman, 1922, in Bosworth, *Geology and Palaeontology of N.W. Peru*, 138. Measurements from a thin section of a specimen from Calita Sal, N.W. Peru,

Genus Discocyclina Gümbel, 1868.

Sub-gen. *Actinocyclina* Gümbel, 1868.

Vaughan, in 1926 (*Proc. Nat. Acad. Sci.*, xii, 534), described the occurrence of fragments of "a four-rayed species of *Asteriacites*" in a collection of foraminifera from the sea coast of Ancon, south-west Ecuador. The present collection includes one perfect specimen from this locality, and two from well samples, which agree with Vaughan's definition—as four-rayed and also possessing embryonic chambers of the same size and shape. The size and shape also agree with specimens of *Cisseis asteriscus* Guppy from Trinidad. *Asterocyclina* has been defined (Gümbel, Douville, Vaughan, etc.) as possessing radiate median chambers, the number of arms ranging from five to more than twelve; the ends of the rays projecting and determining the shape of the test. *Actinocyclina* on the other hand possesses a radiate structure in a test which is circular in outline, the surface showing many elevated rays, generally more numerous than in the case of *Asterocyclina*.

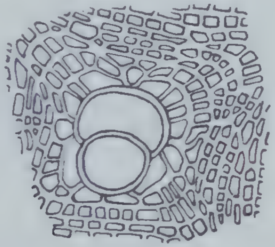


Fig. 3.—Embryonic apparatus of *Actinocyclina* cf. *asteriscus* (Guppy). × 80 approx.

From the small number of rays and the close similarity to *Asterocyclina asteriscus* (Guppy), the species from Ancon should be placed in the sub-genus *Asterocyclina*, but since the outline is circular and the test shows four elevated rays in the central portion only, there are equally valid reasons for assigning it to the sub-genus *Actinocyclina*. It is therefore suggested that *Actinocyclina* and *Asterocyclina* show distinct tendencies to overlap in this particular case. and that some species of *Actinocyclina* may be the adult forms of certain at any rate of the Asterocyclines.

Actinocyclina cf. *asteriscus* (Guppy). (Pl. XXI, Figs. 3, 5, 6.)

1866. *Cisseis asteriscus* Guppy, *Q.J.G.S.*, xxii, 584, xxvi, Fig. 19.
1928. *Cisseis asteriscus* Guppy, Nuttall, *Q.J.G.S.*, lxxxiv, 105, q.v. for further references.

The most perfect specimen was well preserved, circular in outline, and lenticular in cross section, the surface being finely papillate.

The centre showed a raised central portion in the form of four short arms arranged at right angles to one another, and only reaching about half the distance from the centre of the test to the circumference.

A section revealed the presence of a typical Asterocycline median layer which passed into a Discocycline arrangement towards the periphery (see Pl. XXI, Fig. 5). The embryo was small, reniform, and typically Discocycline, surrounded by a ring of irregular cells similar to those figured by Schlumberger for *Orthophragmina stellata* (*Bull. Soc. géol. France*, **4**, iv, 1904, p. 127, fig. 5). This ring is shown in Pl. XXI, Fig. 6, and in Text-fig. 3 and is followed by the usual type of rectangular Discocyline cells, lengthened in four places to produce the rays.

Measurements, as compared with Vaughan's specimens of *Asteriacites* cf. *georgiana* from Ecuador and specimens of *Cisseis asteriscus* Guppy, from Trinidad, are given in the subjoined table :—

Character.	*Cisseis asteriscus* Guppy,[1] Trinidad.	Ancon.			Vaughan's specimen.[2]
		Specimen 1.	Specimen 2.	Specimen 3.	
No. of rays	Four	Four	Four	Four	Four
Shape of embryo	Reniform	Reniform	Reniform	Reniform	Reniform
Diameter of initial chamber	90–120μ	90μ	100μ av.	105 × 88μ	80μ
Diameter of 2nd chamber	150–175μ	120μ	144μ	140μ	160μ
Total breadth of embryo	150–185μ	190μ	190μ	175μ	—
Walls of embryo app.	9–10μ	14μ	14μ	10·5–14μ	—
Dividing wall	Curved	Curved	Curved	Curved	—

In the large and most perfect specimen from Ancon Point, the diameter is 8 mm., and the thickness through the raised central portion 1·0 mm. The section shows that the stellate portion of the test extends to a diameter of approximately 4·5 mm., hence, if growth is by addition of successive annuli the form must have been at first strongly stellate, then quadrangular, and finally circular. It is therefore suggested that we are dealing with a specimen of *Cisseis asteriscus* Guppy (= *Asteriacites asteriscus* (Guppy) Vaughan) which has reached a much more advanced stage of growth than is usually found.

The annuli vary a little in width, but those in the circular portion of the test are made up of cells approximately 40 (radial) × 20μ (transverse), the walls between chambers in adjacent annuli alternating fairly regularly.

[1] Measurement of specimens on slides 250–1, 574–6, in the Sedgwick Museum, described by W. L. F. Nuttall from Trinidad.

[2] *Proc. Nat. Acad. Sci.*, xii, 1926, 534.

The section further shows the presence of numerous pillars fairly widely separated. Owing to the extreme scarcity of material it was not possible to obtain a vertical section.

Material.—Thin sections C. 400–C. 402.

Genus HELICOLEPIDINA Tobler, 1922.

Helicolepidina polygyralis sp. nov. (Pl. XXII, Fig. 5.)

Several specimens of *Helicolepidina* were found which did not differ from *Helicolepidina spiralis* Tobler in external appearance, but which showed a very marked difference in thin section. The specimens were 2·0 mm. to 2·2 mm. in diameter, and 0·8 to 0·9 mm. in thickness, the ornament being indeterminate.

The embryonic apparatus (Fig. 4) is similar to that of *H. spiralis*, being isolepidine, but in all the specimens sectioned is considerably smaller. The initial chamber averages 90–100μ, the total embryonic apparatus having a breadth of from 150μ to 180μ, and the wall between the two cells is slightly curved. The outer wall of the apparatus appears to vary from 20–25μ in thickness. The principal difference from *H. spiralis* lies in the coiling of the spiral of larger chambers. This can be clearly seen by comparing the figures of the Ecuadorian specimen (Pl. XXII, Fig. 5) with a typical specimen from Trinidad (Pl. XXII, Fig. 6).

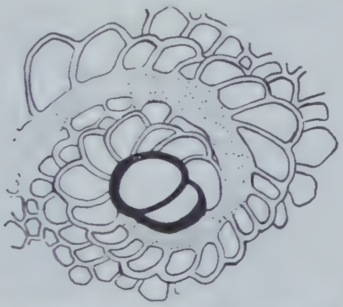


FIG. 4.—*Helicolepidina polygyralis* sp. nov. *Camera lucida* drawing of the embryonic apparatus and the early chambers of the spiral series. × 67 approx. (C. 403).

In the specimens of *H. spiralis*, the spiral reaches the periphery of a test up to 3·5 mm. in diameter in about one and a half whorls, or even less. In all the Ecuadorian species sections, the spiral takes at least two and a half, and sometimes as many as three whorls to reach the periphery of a test only 2·2 mm. in diameter. A specimen showing this character has been figured from Peru, by Willard Berry (*Johns Hopkins Studies in Geology*, No. 9, 1929, pl. xxii, fig. 2, p. 37), although in his description this fact is ignored, and the specimen is described as a typical *H. spiralis*.

In vertical section very little difference can be observed between the two species, except that the Ecuadorian species appears to possess a slightly thinner equatorial layer.

Holotype.—C. 403. *Paratypes.*—C. 404.

A figure is included (Pl. XXII, Fig. 2) of a very peculiar specimen of *Helicolepidina* from the same deposit as the above. The test is slightly larger, and inclined to be sellaeform, possessing an irregular outline, the surface being covered with medium-sized granules. A section shows the presence of the typical spiral extending through three complete whorls, but although this spiral reaches the centre, no nucleoconch of the usual form is visible, nor was any sign of one observed while rubbing down the specimen.

It is suggested that the specimen is a microspheric *Helicolepidina*, the dimorphism of this genus not having been observed previously so far as the author is aware. The specimen (C. 408) is deposited with the remainder of the Ecuadorian Foraminifera in the Sedgwick Museum, Cambridge.

The numbers C. 382, etc., above are the Register numbers of the specimens in the Sedgwick Museum.

EXPLANATION OF PLATES XXI AND XXII.

Plate XXI.

FIG.

1.—*Discocyclina anconensis* sp. nov. × 23. Equatorial section of specimen on slide C. 386. From Ancon, south-west Ecuador.

2.—*Discocyclina sheppardi* sp. nov. × 21. Equatorial section of specimen on slide C. 392. From Ancon, south-west Ecuador.

3.—*Actinocyclina* cf. *asteriscus* (Guppy). × 17. Tangential section showing arrangement of pillars (C. 400).

4.—*Discocyclina anconensis* sp. nov. × 26. Equatorial section (C. 387).

5.—*Actinocyclina* cf. *asteriscus* (Guppy). × 17. Equatorial section showing radiate arrangement (C. 400).

6.—*Actinocyclina* cf. *asteriscus* (Guppy). × 118. Equatorial section showing the nucleoconch and the surrounding cells (C. 400).

Plate XXII.

1.—*Discocyclina* aff. *weaveri* var. *parvipapillata* Vaughan. × 25. Transverse showing the thickening of the median layer towards the periphery. Guayaquil Limestone, Guayaquil (C. 382).

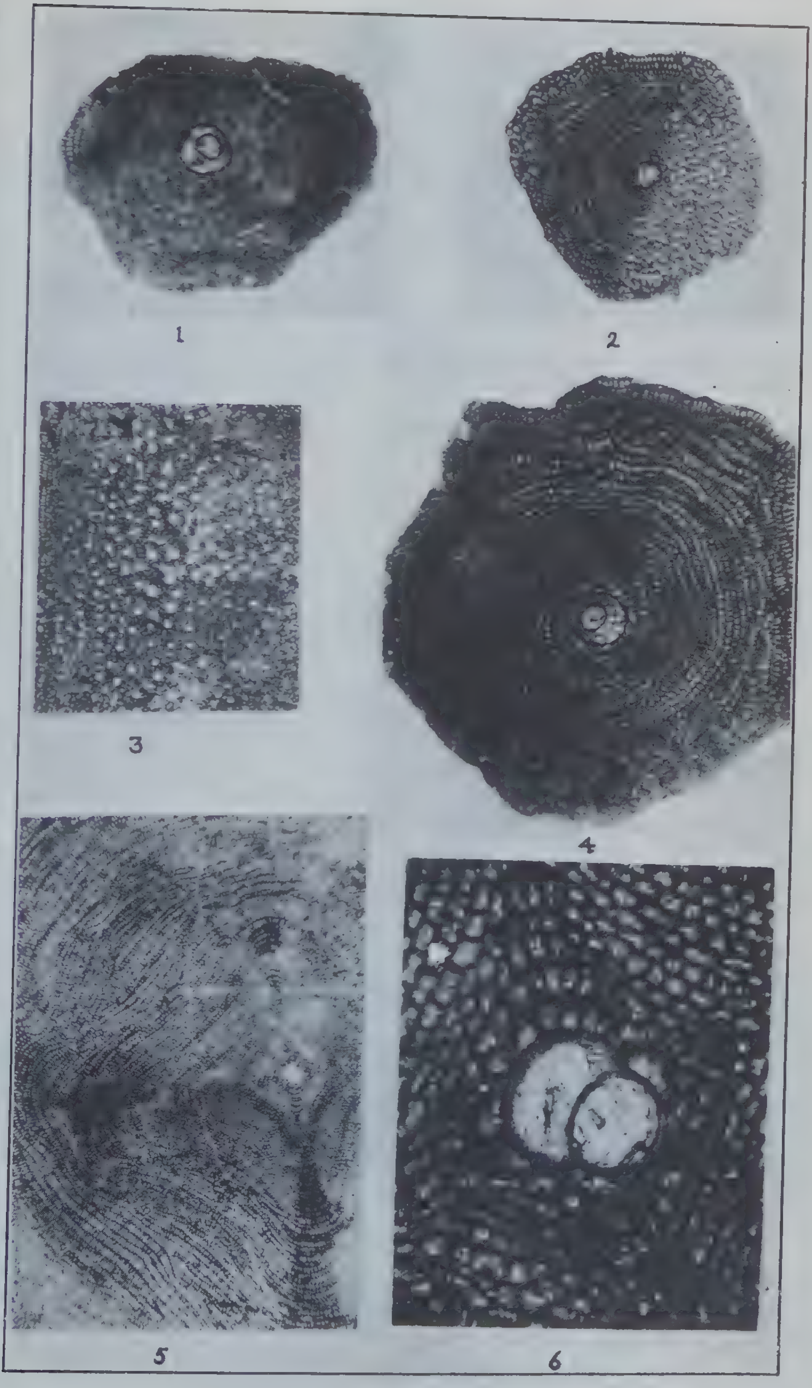
2.—*Helicolepidina* sp. × 26. Equatorial section of microspheric form from Ancon Point (C. 408).

3.—*Polylepidina* sp. × 30. Equatorial section of specimen from the Socorro Series, Ancon Point (C. 409).

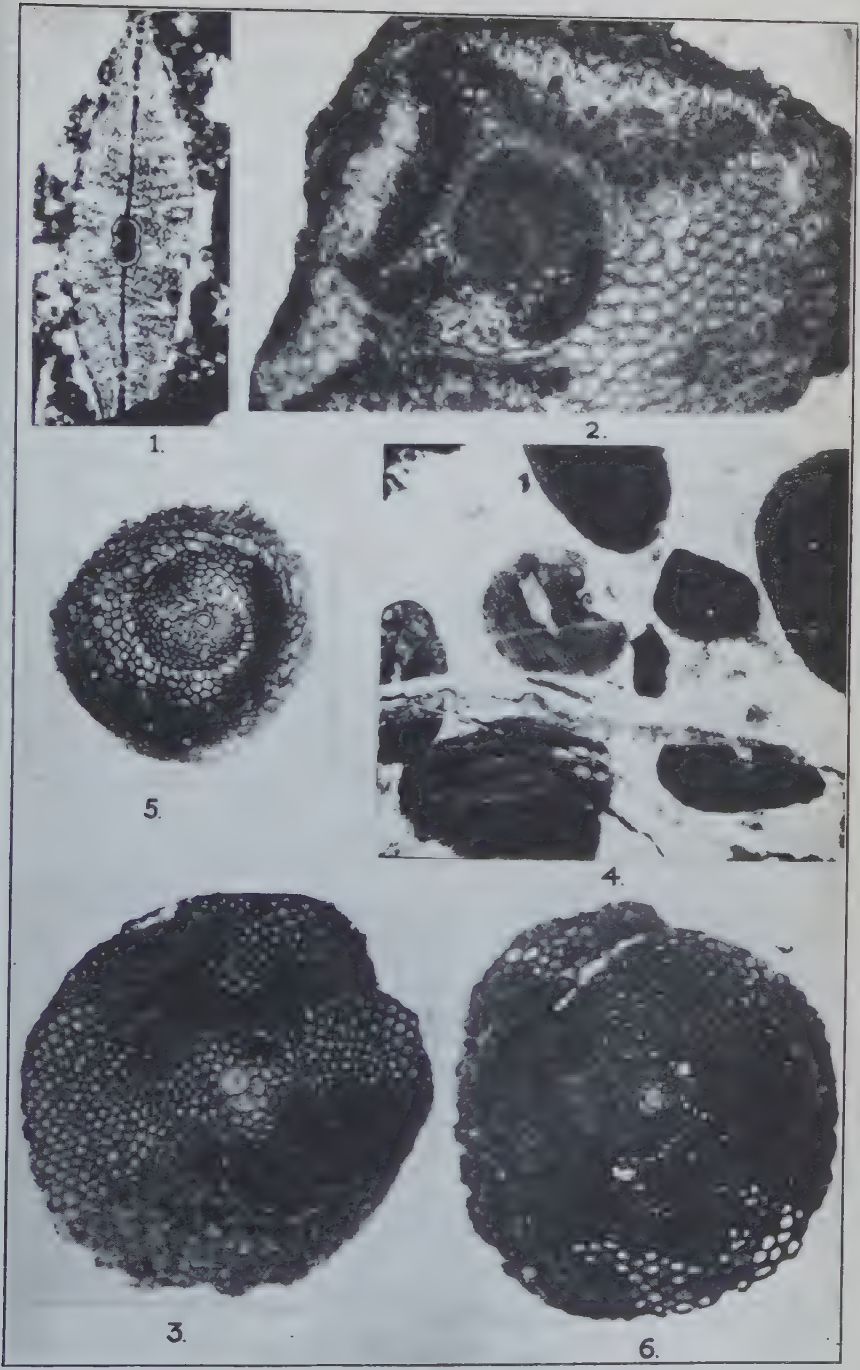
4.—Section of Guayaquil Limestone showing *Archaeolithothamnium* sp. × 25. (C. 383).

5.—*Helicolepidina polygyralis* sp. nov. × 17. Equatorial section of specimen from Ancon Point (C. 403).

6.—*Helicolepidina spiralis* Tobler. × 17. Equatorial section of specimen from Trinidad (figured Nuttall, *Q.J.G.S.*, 1928, vol. lxxxiv, pl. viii, fig. 4) for comparison with Fig. 5.



Discocyclina FROM ECUADOR.



Helicolepidina, ETC., FROM ECUADOR.

The Influence of the Desert on the Deposits in the Red Sea.

By Zbigniew Sujkowski.

THE study of recent sediments has yielded important data bearing on the extent and conditions of deposition in ancient seas, but the collection of similar data relating to the ancient continents is more difficult. However, one may find in marine deposits some indirect evidence of the constitution of the neighbouring continents. The effect of the proximity of deserts on the composition of recent marine deposits does not appear to have been studied. With a view to collecting data bearing on this particular point, I have made an examination of the deposits of the Red Sea.

I turned my attention particularly to the Red Sea on account of its special geographical situation. It is surrounded on all sides by deserts. No important river, such as would add detrital material from its shores, enters it, and erosion does not play any important part in contributing to its deposits except in the immediate neighbourhood of the coast. In the open sea, where depths, as far as is known at present, range to 2,189 metres, detrital material must be entirely wind-borne. The material at my disposal for this study was collected from soundings made by s.s. *Endeavour* in the middle and south-eastern part of the Red Sea in 1927 and 1928. For facilities to study this material I am indebted to Dr. W. T. Calman, Keeper of Zoology in the British Museum (Natural History), and also to Dr. L. J. Spencer, Keeper of Minerals in that Museum, for the loan of apparatus.

Before discussing the influence of the surrounding deserts on the composition of these Red Sea deposits, I would make a few remarks on their general character. As the material available is very limited, I have not attempted to give a general description of the deposits as a whole.

The coral reefs and oolitic beaches of the Red Sea have been described by earlier writers, but of the deep-water deposits we have hardly any information. The bottom samples collected by s.s. *Endeavour* have not been studied previously, nor have we any geological data from the work of the Austrian expedition in the warship *Pola* which investigated the northern end of the Red Sea in 1896. Outside the coral reefs and beaches, shallow-water deposits consist of grey sand with shells and grey mud. It is not possible to define exactly the limit of these shallow-water deposits, but it appears to be between one and two hundred metres.

The deep-water deposits, which are the ones with which I am concerned, are yellow, pink, or pale grey in colour. They are composed of material of animal origin, mainly of the shells of planktonic animals. *Globigerina* predominates. They differ from the analogous deposits of the deep oceans in the great part played by pteropods and heteropods. The remains of benthonic animals play no part in their composition. In every sample there is a more or less important proportion of detrital material derived from the continental dust, and it is on this material that my attention has been concentrated. This detrital material cannot have been brought in by currents or rivers. It could have come only from the desert. It is of no importance for the present purpose to know whether it came from the east or from the west. For this investigation the authigenic minerals of the deposits are of no value, but it may be of interest to record that pyrites and glauconite, usually the commonest of the authigenic minerals, have not been found.

Among the detrital minerals some species are found in every sample; these I consider as derived from the continental dust. Certain minerals found sporadically at single stations or only in a few samples may be explained by local conditions.

In order to study the detrital minerals a small portion of each sample was treated with hydrochloric acid. The insoluble residue was divided by a water-current into two portions: (*a*) the finest washings containing particles less than 0·005 mm. in diameter, and (*b*) the remainder with particles larger than this limit. The material obtained from each sample was mounted in Canada balsam for examination. In the finest washing the detrital particles consist mainly of clay and iron oxides, brown or red in colour. The presence of these iron oxides might be taken to indicate that the Red Sea deposits are completely oxidized, the oxides being formed in situ, but I consider this doubtful and prefer to regard them as truly detrital.

Most interest attaches to the grains which exceed 0·005 mm. in diameter. These are very angular in every sample taken far from the coast. Only in very shallow water and near the shore are rounded grains found mixed with the smaller angular grains. Crystal forms are not recognizable except in zircon, which is very rare. In size they range up to 0·06–0·07 mm. in diameter, but mica flakes reach twice this size, being exceedingly thin and easily transported by wind. In variety they are remarkably uniform; all stations yield an almost identical residue of mineral grains, and it would be difficult to distinguish between one and another.

The mineral assemblage has four important characters:—

(1) Rareness or absence of common heavy minerals like zircon (rare), rutile (not noted), garnet (not noted), tourmaline (very rare), and others.

(2) Abundance and predominance of minerals not very common in detrital sediments, but important as main rock-forming minerals of igneous and metamorphic rocks, such as different amphiboles, pyroxene, biotite, lime-soda and potash felspars, and felspathoids.

(3) Low content of quartz in the mineral residue.

(4) Preponderance of coloured minerals over the colourless.

The above-mentioned mineralogical characters of the detrital residues are especially interesting and important. They are entirely in accord with the character of the weathering and transport of the mineral material in these regions. The African and Arabian deserts on both sides of the Red Sea are undergoing only mechanical weathering of rocks, without any chemical decomposition. Hence the predominance of unstable minerals in the residues. The small size of the grains and their angularity is also in agreement with air transport. Further, the presence of minerals that are not hard, and their freshness, support the view that water transport has not taken place.

One point of great importance must be noted. It is the complete absence in the deposits of the Red Sea of rounded mineral grains. A similar kind of detrital grain (quartz chiefly), having dimensions 0·2–1·0 mm., met with in some sediments, for example, in white chalk, has been sometimes considered as a proof of the aeolian origin of these grains.[1] Especially has it been regarded as an indication of a desert in the neighbourhood of the Chalk Sea, for this type of rather large and rounded grains of quartz was met in white chalk in England, France,[2] Poland,[3] and elsewhere.

I do not think it is possible still to consider these grains as an indication of aeolian transport. It seems that the rounded grains of desert dunes cannot and could not be transported otherwise than by being rolled along the ground, and thus they cannot have travelled far from the shore. If they were drifted by water-currents they would no longer be aeolian material.

The Red Sea deposits bear some resemblance to the loess, but there is a difference in the qualitative mineralogical composition. The quantity of quartz is much greater in the European loess, but certainly the conditions of the hot desert weathering in the Sahara and Arabia are quite different from those existing in the vicinity of the glaciers during the glacial period. And it is true that the loess of China contains more dark minerals and felspars than European loess.

A great difference is seen between the continental dust of the Red Sea and the mineralogical residues of great oceanic depths. The chief difference lies in the presence of quartz, unknown or almost unknown in the ocean depths ; also there is an absence of volcanic glass and pumice, and their weathering products, such as sideromelane, palagonite, etc.

A resemblance has been noted between the detrital residues of the Red Sea deposits and the detrital composition of some Palaeozoic grauwackes, but this requires further work.

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[1] For example, E. B. Bailey, "The Desert Shores of the Chalk Seas," GEOL. MAG., LXI, 1924, 102–16.

[2] L. Cayeux, "Contribution à l'étude micrographique des terrains sédimentaires . . . II. Craie du Bassin de Paris," *Mem. Soc. Géol. Nord*, iv, part 2, 1897, 207–563.

[3] Zb. Sujkowski, "Petrografja Kredy Polski," *Bull. Serv. Géol. Pologne*, vi, 1931, 626.

To close this short note I may sum up the results.

The influence of a desert may be considered as impressing definite features on the deposits, and it seems possible to establish the proximity of a desert by the recognition in marine deposits of these features, which are :—

(1) The freshness and angularity of detrital grains.

(2) Their small size, which does not exceed 0·06–0·07 mm. (for mica 0·14 mm.).

(3) The characteristic mineral composition, with the predominance of :—

- (*a*) Coloured minerals.
- (*b*) Common rock-forming minerals.
- (*c*) Of easy weathering minerals.

I do not know whether these conclusions may be applied to every desert, or only to every hot desert. Different geological structures in the desert continent and different climatic conditions (hot or cold desert) might and must vary the characters from those seen in Red Sea deposits. Further investigations are needed to determine how great these differences may be.

On the Heavy Mineral Assemblages of the Great Chalky Boulder-clay and Cannon-shot Gravels of East Anglia, and their Significance.

By J. D. Solomon.

In the course of a general survey of the Glacial deposits of East Anglia it has been found necessary to investigate the mineral content of a large number of samples of the well-known "Chalky Boulder-clay" over a considerable area of Norfolk and Suffolk.

The "Cannon-shot" gravels, which have been thought to be associated with this boulder-clay, have also been investigated; and the results of both of these investigations are sufficiently striking to justify separate publication.

The heavy mineral assemblages alone have been subjected to close study; for the lighter constituents do not provide a sufficient variety of minerals to yield any criteria of stratigraphical importance; quartz and felspars are ubiquitous, and that is about all that can be said.

The method of treatment adopted was as follows :—

Some 80 grams of boulder-clay, or somewhat less in the case of gravel, were washed with water to remove argillaceous material, the clay being gently kneaded either with the fingers or with a pestle. The residue was then boiled with strong hydrochloric acid for twenty minutes, washed, and dried. This procedure was unfortunately necessary on account of the large quantity of limonite (often in the form of oxidized casts of glauconite) which was present; if this was allowed to remain, it always carried down with it a considerable quantity of quartz during the subsequent separation with bromoform, and this obscured the character of the genuine non-magnetic heavy residue.

Even after washing the clay with acid, it was sometimes necessary to submit the heavy residue from the bromoform to further acid treatment, as some of the limonite had escaped solution.

The residue when freed from limonite was separated into two fractions by means of the electromagnet. This twofold separation was found to be sufficient for ordinary purposes.

The following minerals were found in the Chalky Boulder-clay:—

(*a*) MAGNETIC FRACTION.

Garnet is by far the most abundant mineral, occurring chiefly in the form of large pink grains which have suffered some degree of rounding. Pale garnet is sometimes present, but is always subordinate in quantity to the pink variety.

Tourmaline occurs, but not abundantly. The grains are always much rounded, and a brown or yellow tint is common.

Staurolite occurs sparingly in large, rounded grains of a light orange-yellow colour, showing the characteristic pleochroism.

Amphiboles are common. Ordinary green hornblende is the predominant variety, but a small quantity of a bluish amphibole, similar to that which is common in the North Sea Drift,[1] is present. The grains are mostly large and as well rounded as the habit of the mineral permits.

Epidote occurs commonly in large grains which mostly show a rather strong lemon-yellow colour. They also generally show the emergence of an optic axis.

Pyroxenes, both rhombic and monoclinic, are of occasional occurrence.

Ilmenite is abundant, and sometimes shows a coating of leucoxene.

Magnetite is scarce.

(*b*) NON-MAGNETIC FRACTION.

Zircon is the commonest mineral, occurring chiefly in rather large grains which are in general much rounded. Good crystal forms are usually decidedly uncommon. Most of the grains are clear, and the purple variety is not abundant.

Rutile is fairly common in large rounded grains of a foxy-red colour; the yellow variety is entirely subordinate.

Kyanite occurs fairly commonly in large grains which usually show some sign of their original blade-like shape, but have nearly always suffered some degree of rounding. They mostly show the cross-cleavage and have an extinction angle of about 30°.

Apatite has been detected in samples which have not been treated with acid. It is not abundant, and occurs in rounded grains which show a somewhat etched surface, due probably to solution.

Andalusite occurs in occasional grains, and is nearly colourless, a faint pink pleochroism being sometimes discernible. It is noteworthy that these grains often yield a positive directions-image, due apparently to the emergence of the obtuse bisectrix from the plane on which the grains lie.

Sphene is of constant occurrence in very small quantity.

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[1] P. G. H. Boswell, *Proc. Geol. Ass.*, 1916, 79–98.

A series of grain-counts yielded the following percentages of the dominant minerals in the magnetic fraction (fifteen samples) :—

Garnet	32·2 per cent.
Tourmaline and staurolite	4·2 ,,
Epidote	9·3 ,,
Hornblendes	7·4 ,,

Tourmaline and staurolite are included together as it appears that the abundance of the one usually coincides with that of the other ; it is therefore probable that they are derived from a common source.

The balance (some 47 per cent) of the magnetic fraction is composed of ilmenite, apart from a few occasional grains of pyroxene, magnetite, etc.

In addition to the minerals enumerated above, marcasite, siderite, dolomite, and a little grey rutile were found in a few samples from East Suffolk ; these were accompanied by small grains of pale garnet, green hornblende and epidote, and were plainly derived from local Eocene outcrops ; they were not found anywhere to the west of the Eocene boundary.

No consistent difference could be detected between the residues from the Chalky-Jurassic boulder-clay and the boulder-clay in which the matrix was predominantly chalky ; from which it is to be inferred that the contribution of the fine-grained Jurassic deposits towards the heavy mineral assemblages was negligible.

ORIGIN OF THE MINERALS.

Clearly, the most significant features of the assemblage described above are :—

(i) The extraordinary abundance of limonite, which is in marked contrast to the content of the North Sea Drift and even of the Marly Drift of North Norfolk.
(ii) The predominance of pink garnet ; notably its occurrence in very much greater quantity than tourmaline and staurolite.
(iii) The general predominance of amphiboles and epidote over tourmaline and staurolite.
(iv) The constant occurrence, although only in small quantity, of andalusite.

It is clear that the limonite is derived from some deposit below the Chalk escarpment ; for the North Sea Drift, which probably contains material derived from all higher horizons than the Chalk, is not rich in this material.

The characteristic rounded grains, with an outer surface possessing almost a polished appearance, are clearly not merely the result of weathering. The most probable source of these grains is the ferruginous horizon of the Carstone, where similar grains have been described by Dr. R. H. Rastall[1] as being very abundant ; far more so, indeed, than any of the other heavy minerals in that formation. The Claxby Ironstone and Roach also provide a possible source of origin. The pink garnet, however, cannot be Neocomian in origin, for although garnet does occur in that formation in Norfolk, it is always accompanied by a much greater quantity of tourmaline and staurolite; also the common Neocomian garnet is pale in colour and smaller in size than that found in the boulder-clay.

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[1] GEOL. MAG., LVI, 1919, 211 and 265 et seq. Ibid., LXVII, 1930, 443.

Similar considerations rule out the possibility of a Jurassic or Triassic origin for this garnet; the common Jurassic garnet occurs in pale, small angular fragments; while tourmaline and staurolite are at least as common as garnet in the Bunter Sandstones.

It seems, therefore, that the source of the garnet must be sought for in post-Cretaceous beds, and the most probable horizon, in view of the commonness of amphiboles and epidote and the constant occurrence of andalusite, is that of the Crag.

It is unlikely that a pre-existing North Sea Drift should have provided much of the material; for in that formation soda-amphibole predominates over ordinary green hornblende, while the proportion of amphiboles and epidote to garnet is much higher than that found in the Chalky Boulder-clay; also, apatite and sphene are quite abundant in the North Sea Drift, being not very subordinate in quantity to zircon and rutile.

In any event, it is clear that the heavy minerals are derived from a deposit lying to the east and north-east of the Chalk escarpment. On the other hand, the content of limonite, as well as the large quantity of Jurassic material in the boulder-clay of Suffolk, provides clear evidence of movement from the westward over East Anglia. It would seem probable, therefore, that ice from the North Sea basin pushed its way inland in a south-westerly direction by way of the Wash Gap, and possibly also other gaps in the Lincolnshire Wolds; and that, having extended for a considerable distance westwards, as shown by the extension of the Chalky Boulder-clay, was then forced, presumably by the pressure of Pennine or Midland ice descending from the north-west, to flow out over the Chalk escarpment into East Anglia. In the north of Norfolk this flow was impossible on account of the continued pressure of ice to the east; there is therefore no true "Chalky Boulder-clay" in that area.

The distribution of that type of boulder-clay which carries much Jurassic material in the matrix coincides with the area opposite the important gap in the Chalk escarpment formed by the valley of the Little Ouse. The writer supposes that *basally* incorporated material could not be transported by ice up a gradient of more than a certain limited steepness; the Jurassic material contained in the lower layers of the ice would therefore not surmount the Chalk escarpment in places where it was well developed. Confirmation of this hypothesis is found in the neighbourhood of King's Lynn, where Kimmeridgic material is found above the low Greensand escarpment at Bawsey, but does not surmount the higher Chalk slope to the east. The Pliocene material, however, being derived from further afield, and therefore having attained a higher level in the ice-sheet, would be carried over all but the greatest slopes, and therefore all over Suffolk.

It is noticeable that the Chalky-Jurassic boulder-clay is often overlain by a few feet of chalky clay without Jurassic debris ; this upper layer has been taken, especially by archaeologists, for a later glacial deposit, and has been termed the " Upper Chalky Boulder-clay ". Its existence has generally been attributed by geologists to weathering of the underlying boulder-clay, the Jurassic material being " bleached ". The writer considers both these explanations improbable ; the general similarity of the heavy minerals of the upper layer with those of the underlying clay, together with the absence of any intervening surface of weathering, may be taken to rule out the first alternative ; the second explanation seems unconvincing, since the upper layer shows little sign of decalcification, and in any event the weathering of Jurassic clays does not result in bleaching, but rather in the oxidation of the iron content and the resultant production of a brown colour.

The writer believes that this upper layer represents the content of the upper part of the ice-sheet, which was carrying material derived from further afield than that contained in the lower part of the ice. The relative abundance of Liassic material and other erratics, such as Cheviot rocks and Carboniferous Limestone, in the Chalky-Jurassic boulder-clay, as compared with their scarcity or absence in deposits of the usual chalky type, suggests that they were probably derived from the same district as the Jurassic material, that is to say, from an earlier glacial gravel spread out over the Fenland. The existence in the Trent Valley of glacial deposits earlier than the Chalky Boulder-clay was long ago pointed out by R. M. Deeley,[1] and an extension of these deposits into the country occupied by the clays of the Upper Jurassic seems by no means improbable.

Of further significance in this connection is the predominance of grey flint of Lincolnshire type in the Chalky Boulder-clay. Even where it rests upon Upper Chalk with black flint the latter does not seem to occur in it in any marked quantity. It would seem, therefore, that nearly all of the material of the Chalky Boulder-clay is derived from a considerable distance ; and this point raises many questions as to the conditions under which material is incorporated by an ice-sheet and transported any considerable way from the place of its incorporation.

The writer considers that while incorporation may be more or less uniform, transport is far more likely to occur if material is incorporated on a downward slope, for the derived material has then a greater chance to reach a comparatively high level in the ice, flowing *over* that ice which already occupies the lower ground below the point of incorporation.

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[1] *Q.J.G.S.*, xlii, 1886, 437–80.

Thus in the case of the Chalky Boulder-clay, apart from the Pliocene material which has probably been brought from a great distance over a flat sea-bottom, the predominant material assimilated and transported consisted of Lincolnshire Chalk and Carstone, both of which afforded escarpments *down* which the ice must have flowed. Ice impinging against an upward slope is far more likely to redeposit locally incorporated material against the slope, thus giving rise to structures of the type described by Dr. G. Slater.[1]

THE CANNON-SHOT GRAVELS.

The writer's investigations point strongly to the theory that these gravels are of more than one age. This conclusion arises from the apparently legitimate assumption that, if a glacial gravel proves on investigation to contain an entirely different assemblage of minerals from that of the local boulder-clay, the two are not derived from the same ice-sheet.

In central and west Norfolk there appear to be two series of gravels, both of which, from their lithology, merit the name of "Cannon-shot". The one series is closely associated with the Chalky Boulder-clay and possesses a mineral assemblage similar to that of that deposit. The other, which appears to be the later of the two, and to be connected with certain recent-looking examples of glacial topography, contains little or none of the Pliocene garnet and amphibole characteristic of the Chalky Boulder-clay, but contains a considerable proportion of tourmaline, staurolite, and unrounded blades of kyanite, often associated with large quantities of ilmenite and very well-formed small crystals of zircon and red and yellow rutile. The ilmenite often forms as much as 60–70 per cent of the magnetic residue. Limonite is abundant as before. Such garnet as occurs is mostly pale or brownish in colour, angular, and small in size. Small grains of epidote also occur. Sphene and andalusite are very scarce or completely absent.

Certain samples proved to be very rich in pale garnet, together with angular flakes of tourmaline and some topaz.

It would appear that all the heavy minerals contained in Cannon-shot Gravel of this type are referable to Neocomian and Jurassic sources; in some cases this derivation is confirmed by the presence of blocks of Spilsby Sandstone, septaria from the Kimmeridge Clay and other Mesozoic debris; this is in marked contrast to the older type of Cannon-shot, which consists almost entirely of the characteristic rounded flint pebbles.

In the Breckland country much Bunter material is also to be found in these gravels; this may possibly be derived from Triassic sources, but has more probably passed through a Pleistocene gravel.

It appears, then, as if the later ice-sheet came from a more westerly centre than that which was responsible for the deposition of the

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[1] "Glacial Tectonics as Reflected in Disturbed Drift Deposits," *Proc. Geol. Ass.*, xxxvii, 1926, 392–400, and other papers.

Chalky Boulder-clay. As, unfortunately, not much is known of the glacial history of west Lincolnshire and Leicestershire, it is impossible to effect correlation of this episode with anything further to the west.

As a corollary to this work, it may be added that, with the aid of a prospecting pan, it should be possible to distinguish in the field between the deposits of the various glacial episodes in East Anglia; any sand or gravel (except in north Norfolk) which does not, on panning, yield a large crop of rounded grains of limonite may be safely referred to a period earlier than that of the Chalky Boulder-clay; while in a limonitic concentrate the absence or scarcity of pink garnet points to the deposit in question belonging to the post-Chalky Boulder-clay glaciation. This last test is not, however, quite infallible; for along the western boundary of the Fens the newer gravel sometimes contains a considerable quantity of pink garnet, associated, however, with much tourmaline, and especially staurolite, but these latter minerals do not show up well under the hand lens in the presence of large quantities of limonite.

The Gault at Compton, Surrey.

By F. A. Lea.

EXCAVATIONS for a new road in Whiteacre Copse, north-west of Compton, Surrey, have afforded an exceptionally good opportunity for collecting fossils from the Lower Gault of this district. Unfortunately, though the cutting passes through the whole thickness of the formation, it is very shallow in the higher parts, and no specimens could be obtained from the Upper Gault. But three unrecognizable impressions of ammonites were seen at the base of this Upper Gault. The tilt of the strata here is 30° N.

The junctions with the overlying Upper Greensand and underlying Folkestone Beds are exposed. The former was supposed to be cut out at the surface here by a fault, but it is now shown to be present, though probably in part only. The base is all that can be seen. It consists of a hard and blocky, grey sandstone, containing thin seams of calcite. This rests directly upon the light blue Upper Gault.

The total thickness of the clay is about 125 feet. The junction between the Upper and Lower Gault probably occurs at 90 feet from the base where there is a seam of brown loam, 5 feet thick. The higher part of the Upper Gault, however, becomes little more than a subsoil, and no impressions of *Inoceramus sulcatus* were noticed anywhere.

The Lower Gault is darker in colour than the Upper and more plastic. The base consists of a dark greenish-grey loamy sand, about 3 feet thick, interspersed with phosphatic nodules (containing occasional fossils, but no ammonites) and ferruginous concretions.

The sand grains are large, and there are many crystals of selenite. This rests on light green sand which becomes yellow further down.

In the soil above this bed were found two fossils, evidently washed out of the Upper Gault; they are *Hamites intermedius* and *Prohysteroceras goodhalli.* The following ammonites from the Lower Gault have been identified by Dr. L. F. Spath:—

From	0 to 6	ft.	from the base,	*Hoplites* (*Euhoplites*) *loricatus* (early mut.).
,,	6 ,, 15	,,	,,	*H. dentatus.* *H. canavarii.*
,,	15 ,, 24	,,	,,	*H. canavarii.* *H.* (*Euhoplites*) *loricatus.* *H. bonarellii.* *H. canavariformis.*
,,	24 ,, 31	,,	,,	*H. canavarii.* *H.* (*Anahoplites*) *intermedius.* *H.* (*Dimorphoplites*) *pinax.*
,,	31 ,, 48	,,	,,	*H.* (*Anahoplites*) *intermedius.*
,,	48 ,, 57	,,	,,	*H. dentatus.*
,,	57 ,, 69	,,	,,	*H.* (*Anahoplites*) *intermedius.*
,,	69 ,, 73	,,	,,	*H.* (*Dimorphoplites*) *pinax.* *H. dentatiformis.* *H.* (*Anahoplites*) *intermedius.* *H.* (*Dimorphoplites*) *niobe.*
,,	73 ,, 90	,,	,,	*H.* (*Dimorphoplites*) *glaber* (early mut.).

It will be seen that these forms all belong to the lower part of the Lower Gault (beds I–III, or *dentatus* to *niobe* sub-zones of Dr. Spath's classification), so that, if the Upper Gault begins at 90 feet up, a good deal of the higher part of the Lower Gault is missing. But at Albury, to the east of Guildford, the basal Lower Gault is similarly overlain directly by Upper Gault, according to Dr. Spath.

Elastic Instability and Geology.

By Harold Jeffreys, M.A., D.Sc., F.R.S.

IN the February number of the GEOLOGICAL MAGAZINE, Mr. A. J. Bull illustrates an interesting experiment on a type of deformation in a sheet of elastic material subject to a contraction. The inferences he draws from it, however, need further discussion. An elastic solid, under sufficiently great stress, will develop a permanent deformation either by continuous yield or by fracture, according to the nature of the material. The stress needed to produce such deformation may conveniently be called the *strength.* But in certain circumstances it is possible for a stress to produce a considerable change of shape before the strength is reached, and such phenomena are common in engineering practice. A simple example is provided when a rod of india-rubber is compressed longitudinally. So long as the force applied is not too great the rod remains straight; but at a certain critical value of the compression it suddenly buckles sideways into an arc. The straight form is still a possible position of equilibrium, but it is no longer stable, and the slightest disturbance grows until the rod has become strongly bent, giving a new and stable position of equilibrium. It is easy to verify in this case that the strength has not been reached; we need only remove the thrust on the ends, when the rod returns to its original straight form. Another example is provided by a flywheel on a long shaft. Steady rotation is possible at all speeds; but there is a critical speed at which instability develops. Then it becomes possible for the rod to bend and to carry the centre of the flywheel around a circle of finite radius; the tendency of the rod to recover its form provides just enough force to keep the centre of the wheel moving in a circle. Any further increase of the speed of rotation will make the shaft bend through a considerable angle, with disastrous consequences. Other known cases arise in the collapse of tubes under external pressure or longitudinal thrust.[1]

In some of these cases the deformation produced by elastic instability is permanent, in others it is not. In all of them the stress needed to give instability is less than the strength, and in the first stages of the deformation this is still true; but when the deformation becomes large a new set of internal stresses arise, which may exceed the strength of the material, and then a permanent distortion is acquired. In the case of the rubber rod, for instance, the original form may be recovered after considerable distortion; but if the distortion becomes too great the rod will break across. In a ductile material, on the other hand, permanent deformation may be acquired at an early stage. But in any case such deformation is not a direct consequence of the stress applied externally; it is a by-product of the elastic instability. It is fundamentally different from what happens when we distort a lump of plasticene by working it in the hand, or when a block of material breaks in a tensile or crushing test; in these cases the stress reaches the strength before there is any change of form visible to the eye.

The phenomenon noticed by Mr. Bull is evidently a case of elastic instability; the deformation shown in the photographs is less than would give any permanent yield in rubber, and the patterns show tendencies to regularity that are customary in instability but not in fracture. If then it was to have any application to mountain formation we should need evidence that in the actual conditions in the earth's crust compression will give instability before yield. Now instability is resisted by two sets of factors: first, the elasticity of form of the material; second, gravity. In experimental cases the former is dominant, and even then it is only in special circumstances that instability can arise. If, for instance, a rod is sufficiently thick in comparison with its length, we cannot make it unstable, however much we compress it. If a brass tube is made of material sufficiently thick in comparison with the radius, external pressure will never make it collapse. But if a rod or a sheet is sufficiently thin, we can produce elastic instability before crushing by applying a suitable stress along its length or in its plane. The deformation is pure bending; the material on the outside of the bend is stretched and that on the inside is compressed, but the central line or plane is unaltered in length. But bending brings its ends closer together and the work done by the external forces in pushing them together supplies the elastic energy involved in bending. Now the earth is solid, with a finite rigidity, for about the outer half of its radius, and the first condition for instability is not satisfied. But it may be possible to imagine circumstances in which the rigidity of the greater part of the solid portion is not available for resisting deformation, and it is worth while to consider what would happen if there was only a thin crust floating on a heavy fluid. In these circumstances gravity ensures that contact is maintained everywhere; where the crust is depressed, it has to push the fluid down against its pressure, and where it is raised the fluid rises with it. In both cases any deformation of the crust requires work to be done against gravity as well as against elasticity. Now it happens that, for a given supply of energy from the initial stresses, gravity is most effective in resisting distortion for the longest wave-lengths, while elasticity is most effective for the shortest wave-lengths. The condition that instability may develop before fracture, when the effects of the curvature of the earth are neglected, has been obtained by S. Goldstein[1]; a simplified version is given by me in the second edition of *The Earth*, p. 288. The result is that gravity and elasticity together will keep the crust thoroughly stable for all wave-lengths if it is more than 12 metres thick. This estimate is so low as to put elastic instability out of the question.

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[1] See especially Professor R. V. Southwell, *Phil. Trans.*. A, 213, 1913, 187–244.

A complete analysis, allowing for the curvature of the earth, has not yet been carried out; but it is known that curvature makes for stability. Its importance arises chiefly from the fact that a complete spherical shell, unlike a rod or a plane sheet, cannot be deformed without changing the length of arcs in the surface that lies midway between the upper and inner surfaces of the shell. Any deformation stretches this sphere in some places and compresses it in others, so that the curvature makes an addition to the elastic energy required for a given deformation in the case of a plane.[2] For deformations in which the elevation changes from positive to negative in a horizontal distance that is a small fraction of the radius, this extra energy will be small compared with the energy of bending, and Goldstein's theory will need only trivial correction. He estimates that the wave-length of the disturbance excited in a crust just thin enough to become unstable at all would be about 6 kilometres; disturbances of longer or shorter wave-length could arise, if at all, only in still thinner crusts. Since the longer wave-lengths cannot arise in the plane case, *a fortiori* they cannot arise when curvature is taken into account. We are therefore entitled to say that elastic instability can never arise before fracture as the result of the type of stresses that arises due to the contraction of the earth as a whole.

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[1] *Proc. Camb. Phil. Soc.*, xxiii, 1916, 120–9.

[2] Love, *Mathematical Theory of Elasticity*, 530; or Lamb, *Proc. Lond. Math. Soc.*, xxi, 1890, 119–46.

I may remark in passing that the shrivelling of the skin of an apple due to the drying of the interior seems to be another instance of elastic instability in a thin crust; here gravity is of course not a controlling factor.

Fracture or yield, on the other hand, would not give rise to general puckering. As soon as it takes place anywhere, the stresses around the place that has given way rise to several times their previous values, and the region of yield extends until enough shortening of the crust has been achieved to enable it again to fit the contracted interior without stresses in excess of the strength. The actual stages of the readjustment would be somewhat complicated; I have tried already to sketch them.[1] But in any case the result would be long folded or fractured strips.

The tetrahedral theory, which still shows occasional signs of life, is another appeal to elastic instability, since it supposes a permanent deformation to arise without fracture. But it requires a deformation such that the distance from one place of maximum elevation to another is about a third of the circumference, which would be impossible with any estimate of the thickness of the crust.

I think, however, that elastic instability may be important in some cases of readjustment to local stresses. When, for instance, a series of shale beds are thrown into wave-like folds, it may be the result of instability due to a stress along them; and the formation of schists may also perhaps be partly attributed to this cause.

Recent Discoveries of Dinosaurs in India.

By L. Rama Rao, M.A., F.G.S.

DURING the past few years the Upper Cretaceous rocks of the Trichinopoly District, South India, have been receiving a lot of attention on account of the numerous reptilian remains found in some parts of the formation. Dr. C. A. Matley visited these areas about six years back and collected some specimens—a brief preliminary account of which he has recently published.[2] Almost simultaneously with Dr. Matley, the staff and students of the

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[1] Geol. Mag., LXVIII, 1931, 435–42.

[2] C. A. Matley, "The Cretaceous Dinosaurs of the Trichinopoly Dist. and the Rocks associated with them": *Rec. Geo. Sur. Ind.*, lxi, 4, 337–49; "Recent Discoveries of Dinosaurs in India," Geol. Mag., LXVIII, 274–82.

Geology section, Central College, began to interest themselves in this area and have paid several visits to the very locality from which Dr. Matley has collected most of his specimens. As a result of these expeditions it is gratifying to note that we have been able to collect quite a large number of well-preserved fossil bones, and in the words of Dr. Matley this discovery of ours " is of great importance as it is the first time that Southern India has yielded identifiable remains of dinosaurs ".[1]

As Dr. Matley has observed, most of the bony remains of this area, especially the larger ones, are usually in a very bad state of preservation. The bones as they are lying in the rock are seen to be so disintegrated that it is impossible to take them out in an entire condition. In such cases one has to be content with sketches and descriptions of these bones made as they are seen *in situ* in the field. Even such occurrences are not without interest. For instance Dr. Matley has been able to give us, as a result of his careful examination of what was apparently a " badly damaged bone " a restored outline of a large limb bone, about 60 inches in length, which he describes as being " probably a femur, possibly a humerus ". In one of our expeditions we noticed a remarkable bony structure *in situ*, which on close examination revealed two huge massive bones, each of them more than a yard in length, lying in the form of a V. From a detailed examination of the outline and disposition of these bones it has been shown that the bone forming a longer arm of the V is a femur, while in the other arm, which at first sight looked as if composed of one bone, it was found that we had really two distinct pieces, one lying in continuation of the other, representing the proximal fragments of the tibia and fibula. Judging from the large size and the solid and massive nature of the bones there is no doubt that they belonged to a sauropodous dinosaur.

Of the large number of definitely identifiable bones in our collection by far the most common are the vertebrae. This fact is interesting in view of Dr. Matley's statement that in his collection " not a single vertebra " has been found. These vertebral remains are usually more or less fragmentary in character. Very often we get only the centrum and sometimes only the neural arches—even these parts being much broken. Very rarely we get specimens which are almost entire. One such entire vertebra of an opisthocoelous type belonging to the cervical region of one of the Theropoda, was described by the present writer some time back and the fact of its discovery communicated to the Geological Society of London, where the photographs of the specimen were exhibited at one of the meetings[2] through the kindness of Sir Arthur Smith Woodward, F.R.S. More recently we have been able to collect a fairly good specimen of the second cervical vertebra—the axis.

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[1] C. A. Matley, *R.G.S.I.*, lxi, 4, 349.

[2] *Proc. Geol. Soc. Lon.*, No. 1169, 1st June, 1927, 103.

Of the limb bones, a number of distinctly recognizable fragments are to be found in our collection. These include two good specimens showing the epiphysis of the humerus, the head of a femur, the proximal end of a tibia and some phalangeal elements. We have also another interesting bone which looks like the supraoccipital. A full description of these specimens will shortly be published.

Judging from the material in our collection and those described by Dr. Matley, there appears to be no doubt that these remains indicate the existence during the Upper Cretaceous period of a varied reptilian life in South India—representative of all the three great sub-divisions of the Dinosauria.

A Note on the Gneiss of the Ufipa Plateau, Tanganyika Territory.

By John Parkinson, Sc.D.

DURING a residence of nine months on the Ufipa Plateau, the writer had opportunity for examining the gneissose rocks and associated schists near the village of Namwele, locally well known as the centre of coal-bearing beds, with results summarized in the following note. The position—about 7° 50′ S. lat. and 31° 30′ E. long.—is S.E. of the central part of Lake Tanganyika, and not far from the western edge of the Rukwa Trough.

The reference map is Geol. Survey Tan. Territory, G.S. No. 48.

Taken as a whole, the crystalline rocks are peculiarly uniform over the area examined, about 100 square miles, the majority of igneous origin with remnants (in the writer's opinion) here and there of a sedimentary series, completely metamorphosed, very largely absorbed and consequently showing no trace of their original structure. Into these the gneisses—an older and a younger subdivision—are believed to be intrusive. The average foliation at Namwele is W. 20° N., swinging to W. 60° N. 40 miles to the N.W.

The Older or Aplitic Gneiss is a uniform, typically non-porphyritic rock, salmon-pink in colour, characterized by thin laminæ or lenticles of quartz, the whole having a marked foliation. Ferro-magnesian minerals are rare, microcline and an acid plagioclase the common felspars.

At the "North Camp", a short distance from Namwele, this gneiss is seen to be earlier than another and more basic rock, termed for field purposes the "Rukwa Gneiss", as it is also conspicuous near the boundary fault of the Rukwa Trough, along the descent to the village of Musé.

It is distinguished by conspicuous red phenocrysts of felspar, a high percentage of ferro-magnesian minerals, a massive habit and a rounded as distinct from a slabby type of weathering. Microcline is rare; hornblende, a rhombic pyroxene, epidote, and apatite are accessory minerals. This rock is intrusive into the Aplitic

Gneiss, though it is not suggested that they are other than products of the same magma and consequently closely related. The gneiss of Namanyere, 42 miles N.W. of Namwele by direct road, must be included as a product of the Aplitic Gneiss magma.

Evidences for the existence of a sedimentary series are unfortunately scanty, but at Mlundikwa, a conspicuous hill in the northern part of the area, a medium-grained aplitic gneiss, occasionally full of small pink garnets, contains slabby fragments, wisps, and irregular bands of a basic rock which is believed to be a para-schist.

The crystalline rocks of the Kala kala River, near Musé, in the Rukwa Valley (3,000 feet below the Plateau) differ only in unessential details from the gneisses forming the side of the Trough around Namwele. Gneisses or schists composed largely of muscovite are common, and have been seen also on the Highlands near Wimi Hill.

If, as seems borne out by the field evidence, successive gneiss magmas have invaded and completely assimilated sedimentary rocks of sandy-clay composition, merely metamorphosed recognizable fragments being rare, one would expect the characters of the igneous rock to be dominant in the hybrid. From the examination of an exceedingly good section shown in a valley entering the Kisapa River near Namwele from the east and a short distance below the camp, it appears that the paraschists, often extremely micaceous, grade into all stages of mixed rocks as results of the intrusion of the aplitic pegmatoidal magma, the final product of assimilation being a fine-grained " pepper and salt " biotite-gneiss. The banding is streaky, or the more basic material may form irregular masses or lumps in the surrounding rock, but contortion was not often noticed.

The hybrids differ from the pure aplitic gneiss in containing a greater quantity of biotite, which forms flakes rarely more than 1 mm. across, and occasionally of quartz showing the elongated crystals or thin lenticles characteristic of the intruding rock. Unlike the latter, microcline is rare or absent, and, as was to be expected, the crystallization is non-porphyritic.

A New Species of Fossil Cetacean from Tasmania.

By Professor T. Thomson Flynn, Queen's University, Belfast.

SOME years ago I recorded in the columns of *Nature* the discovery, in the Miocene beds of Tasmania, of a fossil cetacean of the squalodont type.[1] Apart from the value of this specimen in its bearing on the phylogeny of the Cetacea, it is of interest in correlating certain geological horizons of Australia with those of South America in which the same genus has been found.

[1] " Squalodont Remains from the Tertiary Strata of Tasmania," *Nature*, cvi, 1920, 406, text-figures 1 and 2.

The publication of the full description has been held up through the difficulty, being stationed as I was in Tasmania, of being able to compare the skull of this whale with the remains of archaeocete whales in the collections of British and Continental institutions. This comparison can now be made but, in the meantime, I feel that it is important that a description should be published, sufficient to identify the species fully, for the information particularly of Australian and South American cetologists. This description is now appended.

Prosqualodon davidi, sp. nov.

Skull Character.—The skull is in general quite of the cetacean (squalodont) type and has a total length of 54·8 centimetres. The rostrum is about half the total length of the skull. Looked at from above, the rostrum has the form of a triangle with somewhat concave sides. Viewed laterally it is seen to be gently concave on the upper surface so that the end of the snout is slightly elevated. The nasal openings are not so far back as in *Squalodon.* The nasal bones roof the posterior portion of the external nasal chamber. The maxillae almost cover the supra-orbital processes of the frontals. Each supra-orbital plate of the frontal is strongly developed, especially as regards its exposed edge. The zygomatic process of the squamosal is very powerfully developed. The temporal fossa is of medium depth. The supra-occipital is large, shield-shaped, and extends upwards and forwards to meet the frontals, thus preventing the parietals from entering into the formation of the cranial roof. The dorsal surface of the vomer bears an exceptionally wide open groove for the reception of the cartilaginous portion of the mesethmoid. The palatines are well developed, meeting in the midline and extending back between the pterygoids. The latter form a part of the posterior surface of the bony palate. Each ends posteroventrally in a well-developed hamular process. The periotic and tympanic bones are typically cetacean. The mastoid is fully exposed on the ventral side in a wide open groove between the paroccipital process and the postglenoid process of the squamosal. The jugal is very slender, much more so, for example, than is the case in *Squalodon bariense.* Ethmo-turbinal bones are fairly well developed.

Skull Foramina.—A pair of large, olfactory foramina are present in the cribriform plate. The optic foramen, the sphenorbital foramen (foramen lacerum anterius) and the foramen rotundum open into a common sinus externally but are separated by well-developed bony walls internally. The foramen ovale and the foramen lacerum medius are confluent. The basisphenoid is perforated on each side by a " carotid foramen " for the transmission of the internal carotid artery. The ascending plate of the palatine is notched by a large spheno-palatine (orbitonasal) foramen.

Mandible.—The coronoid process is low. The symphysis is of medium length, extending back to the level of the anterior molar. The condyle is small, projecting strongly externally.

Dentition.—

$$\text{I.}\,\frac{3}{3}\quad \text{C.}\,\frac{1}{1}\quad \text{PM.}\,\frac{4}{4}\quad \text{M.}\,\frac{6}{6}$$

Molars.—All molars are two-rooted, with roots connected by an isthmus, which is possibly a vestige of an original third root. The two posterior molars in the upper jaw and the posterior one of the lower jaw are smaller than the others. The molars are closely set in the jaw, slightly overlapping in some cases. The arrangement of the main cusps of the molar teeth is of the type in which there are three anterior and three posterior cusps making, with the main cusp, seven in all.

Premolars.—These have the roots coalesced but separated by a groove almost obliterated in the case of the anterior premolars.

In all teeth the enamel is extremely rugose, the whole surface except the extreme tips of the cusps being covered with nearly parallel ridges often beset with minute sharp denticles.

In general, the skull is very rounded, much more so than is the case in *Squalodon*, approaching the modern odontocoetes in this respect. The bones of the side walls of the skull are inflated, and no post-orbital constriction is present. The bony crests are suppressed as in general in modern odontocoetes.

The whole skull appears in a slight degree asymmetrical, due to the greater development of the bones of the left side.

Locality.—Miocene Beds, Table Cape, Wynyard, N.W. Tasmania.

REVIEWS.

NOTES UPON THE DANA SPECIMENS OF *Spirula* AND UPON CERTAIN PROBLEMS OF CEPHALOPOD MORPHOLOGY. By J. GRAHAM KERR, Regius Professor of Zoology, University of Glasgow. *The Danish "Dana"-Expeditions,* 1920–1922 *in the North Atlantic and the Gulf of Panama.* Leader: Professor Johs. Schmidt. Oceanographical reports edited by the "Dana" Committee, No. 8, with 20 plates, and 8 text-figures, and an appendix by M. W. JEPPS, M.A., University of Glasgow, on a Parasitic Ciliate from *Spirula.*

THIS valuable paper by Professor Graham Kerr "deals with certain points in the anatomy of the rare Cephalopod or Siphonopod *Spirula*, hitherto unknown or incompletely known, and discusses the bearing of *Spirula* on some of the more important problems of Cephalopod evolution".

The archaic Cephalopod *Nautilus* is first discussed, and a summary is given of the chief results of the author's work on this Cephalopod, which was the subject of his first morphological investigation.[1] The familiar Cephalopodium theory, which states that the head is a complex of which the outer portion is of a pedal nature, is discussed in detail and the arguments upon which it is founded are refuted. The effects of the Cephalopodium theory on the use of such descriptive terms as dorsal, ventral, anterior, and posterior are deprecated, and the natural way of describing the orientation of the Cephalopod body is given, i.e., the head is anterior, the tip of the body posterior, the physiologically lower side of the body on which is the funnel ventral, and the upper side of the body dorsal

The specimens of *Spirula* which formed the subject of the present study, were collected in the Atlantic by the Danish Dana-Expedition between 10° and 35° N. latitude. Most interesting facts concerning the habits of the creature are described. A detailed study has been made of various organs of *Spirula*, including the alimentary canal, the coelome, the genital organs of the male, and the nephridia.

The spirally coiled shell of *Spirula*, which in all other surviving Dibranchs has undergone great modification or has entirely disappeared, received detailed description, attention being called to (*a*) its endogastric coiling, (*b*) the character of the coiling, and (*c*) the shape of the protoconch. The importance of (*a*) is the dissimilarity to *Nautilus*, in which the coiling is exogastric; of (*b*) that up to about the thirtieth chamber, the shell is coiled in a plane spiral like that of an ammonite, with the coils, however, not in contact, but that after this the rate of spiral coiling diminishes, until the shell is practically straight. As it is already known that the shell of an ammonite recapitulates in its successively formed portions the record of phylogenetic evolution, Professor Graham Kerr points out the probability that we have in *Spirula* a shell evolving from a coiled to a straightened-out form. The interest of (*c*) is that the protoconch, or initial chamber, is spherical or spheroidal, while the primitive molluscan protoconch was conical like that of *Nautilus*. The continuous increase in the diameter of a conical protoconch permits the continued accommodation of the growing body. In the spherical initial chamber of *Spirula*, however, this is not possible. " The young *Spirula* at the stage when the initial chamber alone was present possessed a shell with a narrow aperture, entirely unadapted to allow the passage of the body through it when the initial chamber was vacated. We may conclude then that the shell of *Spirula* was an internal shell from the beginning, and that it was at no period of ontogeny external as is assumed by Pelseneer and many other authors." Professor Graham Kerr extends this argument to " all the various types of fossil Cephalopods in which the shell had a restricted aperture ", and regrets " the conspicuous neglect of physiological considerations" which is found in palaeontological discussions of Cephalopod evolution.

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[1] *Proc. Zool. Soc. Lond.*, 1895, and *Studies from the Morphological Laboratory in the University of Cambridge*, vi, 1896.

The fragile nature of the ammonite shell and its inefficiency as protective armour; its reinforcement against external pressure by the frilling of its septa; the frequent reduction in size of the last chamber and constriction of the mouth; the restricted aperture of the protoconch, and the frequent large size of the protoconch as compared with the immediately succeeding chambers are all given as arguments in favour of regarding the ammonite shell as having been internal even in early ontogenetic stages.

The large section on the Phylogenetic History of the Cephalopods (pp. 27–33) is of primary importance and interest to palaeontologists. Professor Graham Kerr does not accept the popular view that the straight *Orthoceras*-like shell is the primitive form. While admitting that it is simpler, he gives the following reasons for regarding the Cephalopod shell as having been primitively coiled.

> (*a*) As the Eugastropods, which have a long tubular shell, became coiled at a very early evolutionary stage, it seems probable that the Gastropod-like ancestor of the Cephalopod had a coiled shell.
>
> (*b*) *Nautilus* with its spirally coiled shell is the most archaic of Cephalopods whose anatomy has been studied.
>
> (*c*) From physiological considerations the straightness of the shell points to its being already internal, having evolved beyond the stage of being a protective covering.
>
> Professor Graham Kerr also concludes that the coiling of the primitive Cephalopod shell was exogastric as in *Nautilus*.

The shell of *Spirula* is of interest for its bearing on evolutionary problems. The spherical shape of the initial chamber indicates that the shell was never at any period of its life history external. The shell loses its spiral curvature and becomes straightened out. This ontogenetic sequence is evidence of a similar sequence of spiral and straight shell in phylogenetic evolution. As the shell of *Spirula* is internal, the terminal chamber, which in *Nautilus* contains the whole body, is greatly reduced in size, accommodating only the hinder end of the body. In his consideration of the problem of the endogastric coiling of the *Spirula* shell, Professor Graham Kerr has been influenced by his great experience in unravelling the evolutionary history of the analogous organ of modern fish, the air-bladder. He says that in the primitive Nautiloid condition the shell is "ballasted" through the large terminal chamber being occupied by the animal's body. "With the withdrawal of the body from the shell and the reduction of the terminal chamber after the shell became internal this ballasting effect would be reduced and its place would be taken by an overturning effect due to the gas in the larger and lower chambers. The physical conditions thus set up are exactly those which in the group of fishes have caused the lop-sided Polypterus type of lung to become rotated round within the body into a reversed position, and it would therefore be entirely justifiable to anticipate a similar rotation to come about in the case of the gas-containing receptacle of *Spirula* . . ."

In *Spirula* it has been shown that the resting position of the animal is that of suspension in the water head downwards, the air-containing shell tilting up the hind end of the body. As this tendency to tilt is obviously disadvantageous in rapid movement, the author anticipates that in the course of evolution it would be counteracted, and suggests three ways in which this might be effected; (*a*) by the development of a counterpoise posterior to the shell, which counterpoise of dense calcareous substance forms the rostrum or guard of *Spirulirostra*, *Belemnites*, etc.; (*b*) by the extension of the shell in a headward direction along the dorsal side of the body. This method is seen amongst the Sepioids culminating in *Sepia* in which the ventral side has almost entirely disappeared; (*c*) by the abolition of the gas-filled chambers of the shell. This method is reached by *Sepiola* and the Teuthidae, the shell having lost its hydrostatic function and having become simply an internal supporting skeleton.

A concise account of the evolutionary history of the Cephalopoda is given, with a summary of the various grades in the evolution of the shell. In his concluding remarks, Professor Graham Kerr emphasizes again that " phyletic hypotheses based upon only one organ-system such as the skeleton should, even when provisionally accepted, be kept under very critical scrutiny. Were *Spirula* known only as a fossil it would doubtless be regarded by most palaeontologists as extraordinarily archaic—ranking possibly with *Nautilus* in this respect ".

C. McCallien.

STUDIES OF EVOLUTION IN THE GENUS SPIRIFER. By CARROLL LANE FENTON. pp. x + 436, 50 plates, and 204 text-figures. Publications of the Wagner Free Institute of Science, ii. Philadelphia, 1931.

PROFESSOR FENTON'S work is essentially a detailed study of material carefully collected from successive beds of the Hackberry Formation (Upper Devonian) of Iowa, U.S.A. From the data thus obtained, various ideas concerning evolution are discussed and criticized and new ideas are introduced. The author examined more than 10,000 specimens in the course of his research, which extended over ten years—1920–30. Of these above 7,000 belonged to the *Spirifer orestes* phratry,[1] which includes the *Spirifer varians* and *S. obliquistriatus* gentes, and over 3,000 to the *Spirifer hungerfordi* gens.

The work is divided into two sections and has an introductory chapter on the stratigraphy of the Hackberry Stage by the late C. H. Belanski. Section 7 is devoted to a general discussion and conclusions and covers six chapters dealing with (i) the objects, materials, and methods of research; (ii) taxonomy and nomenclature; (iii) evolution versus fluctuation; (iv) evolutionary trends; (v) rejected theories and hypotheses; and (vi) a physiologic theory of racial senescence. In the last of these chapters Dr. Fenton suggests that phyletic senescence in a race of organisms is brought about by decreasing powers of metabolism.

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[1] The term " phratry " is defined on p. 30 as " A monophyletic or nearly monophyletic group composed of two or more gentes which may differ widely, however, in their evolutionary trends ".

The form and characters of the shells, including minute details of ornamentation are described and discussed and the changes in these are carefully followed through successive zonules. In view of the recent controversies on the subject, it is interesting to note that Dr. Fenton evinces evidence of recapitulation in the *Spirifer* studied.

Section ii is a systematic description of the fossils and is well illustrated by plates and text-figures. An introductory chapter defines very carefully and fully the terms used and discusses the mode of presentation. This renders the descriptions of the species, subspecies, and varieties, in which brevity is achieved by thoroughly explained formulæ, particularly clear and concise.

The value of the work lies in its suggestiveness both in ideas and in technique. One may not agree with the author in all his conclusions, but when he provokes dissension he is interesting and stimulating.

S. S.

INTRODUCTION TO THEORETICAL SEISMOLOGY. By J. B. MACELWANE, S.J., and F. W. SOHON, S.J. Part II: *Seismometry.* By F. W. SOHON, S.J. New York: John Wiley and Sons, 1932. Price 16*s*. 6*d*. net.

TO geologists the first part of this introduction no doubt possesses the greater interest, for it contains a discussion of earthquake phenomena and of the origin and propagation of earthquake waves. The second part is devoted to the theory of seismographs and is largely, though not entirely, based on foreign works on seismometry, such as the fourth volume of the *Handbuch der Geophysik* and Galitzin's *Vorlesungen über Seismometrie.* If it were only to make the results of these books known to English readers, Father Sohon would have done most useful work. His treatment of necessity is mainly mathematical, but to a great extent he has simplified the solution of the differential equations employed. His objects are to enable an observer to understand the principles that underlie his instrument, to test its working and adjustments, and to appreciate its shortcomings. How fully he has succeeded in attaining them will be evident by a glance at such useful sections as those on the horizontal pendulum and its forms of suspension, the methods of recording, amplifying, and damping its movements, and especially that on the Galitzin seismograph and the theory of galvanometric registration.

C. D.

THE GEOLOGY OF THE BRAMPTON DISTRICT, Expl. Sheet 18. By F. M. TROTTER and S. E. HOLLINGWORTH. Mem. Geol. Survey, 1932. Price 5*s*.

THE geology of Sheet 18 (Old Series 106 S.W.) is of considerable interest, as it includes the north-western part of the Alston Block, with the northern half of the great Pennine fault as its western boundary and the almost equally great Stublick fault to the north, separating it from the complex Bewcastle anticline. The western half of the map, which just reaches the suburbs of Carlisle, may for convenience be called the northern part of Edenside and consists mainly of the New Red Sandstone. The glaciation of the area is also of great importance, and this memoir should be read in connection with earlier works by the same authors on the tectonics and the glaciation of the region in general.

The Carboniferous rocks of the Alston block are compared with those of Northumberland and elsewhere: a striking feature is the great difference in thickness of the Lower Carboniferous on the block and in the geosyncline to the north (2,500 and at least 8,000 feet respectively). The Yoredale group D_Y is some 2,000 feet thick. An interesting feature is the preservation of a small coalfield by the Stublick fault, which branches towards its western end.

Turning now to the later rocks, we find that the writers use the eminently sensible name New Red Sandstone and do not trouble themselves unduly about the boundary between Permian and Trias. The Magnesian Limestone of Edenside is correlated with the Upper Magnesian Limestone of the east; the Hilton Plant Beds of the same area are considered to be Middle Permian, although it is pointed out that Dr. Sherlock has found the same facies at various horizons in the east, even as high as the base of the Bunter. The St. Bees Sandstone and Kirklinton Sandstone are equated with the Bunter and the Stanwix Marls with the Keuper. No unconformity has been formed anywhere in the New Red series.

The glacial succession here accepted can only be alluded to very briefly: two boulder-clays are general and well-established with traces of a still older boulder-clay of Scottish origin, thus affording evidence of three advances of ice, with their usual concomitants of sands, gravels, and laminated clays belonging largely to the retreats. The story is completed by river terraces and alluvium in the main valleys and by peat on the hills.

Altogether this memoir is an admirable piece of work, in which a due balance is preserved between all the different aspects of its subject: in particular, the tectonics are dealt with in a specially clear and attractive manner, and it is gratifying to find that increasing attention is now being given to this important side of British geology.

CORRESPONDENCE.

BRIMSTONE HILL, ST. KITTS.

SIR,—In the June number of the GEOLOGICAL MAGAZINE Dr. Trechmann has criticized under several headings the views of previous writers on the structure of Brimstone Hill, St. Kitts. As many of his criticisms apply to my own work, perhaps I may be allowed to offer a few further observations.

I think Dr. Trechmann is probably right in describing the core of the hill as of andesite. In looking over my original description of this rock, I find I determined the rock as an "Andesitic Tuff", which I corrected in the MS. to "Andesite". The same alteration appears on the microsection at the British Museum, though it is there *registered* as "Andesitic Tuff". It was possibly the unique character of the rock, both in the hand specimen and under the microscope, as compared with other West Indian andesites, that led me to follow Spencer's description of the rock as a tuff in my printed report. Or it may be that the report was published and the slides subsequently revised before handing over to the British Museum.

I find it difficult to agree, however, that the mantle of limestone is the relic of beds of Pliocene age which may have underlain the main cone of the island, since it is the only fragment preserved and since igneous activity probably commenced in early Tertiary times. Further, the limestone deposit of Godwin Gut, which occurs at an altitude of 1,150–1,180 feet above O.D., is very probably older than the Brimstone Hill desposit, and can scarcely from its present position have underlain it.

I, of course, agree that the extrusion of the igneous plug is later than the deposition of the sedimentaries, and I state so very clearly in my report (p. 14).

With regard to the detailed analysis of the molluscan fauna of the limestone, Dr. Trechmann has probably more knowledge than myself, but I would point out that he has completely ignored the coral evidence. I do not know if he has studied my paper on Dominica,[1] wherein I list a very similar fauna from other limestone deposits. The curious thing is that all these deposits, which I believe to be of Pleistocene age, appear to be confined to the leeward side of the island.

K. W. EARLE.

GEOLOGICAL DEPARTMENT,
UNIVERSITY COLLEGE,
LONDON.

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[1] GEOL. MAG., Vol. LXV, 1928, p. 169.

CHERT IN THE BARTON PEBBLE BED.

SIR,—In 1912 Messrs. Bromehead and Dewey announced their important discovery of the occurrence of Lower Greensand Chert in the Barton Pebble Bed of the London Basin. Its bearing on the date of the uncovering of the Weald is evident and has frequently been commented on, whilst this supposed source of chert has also been laid under contribution to explain the occurrence of chert in the hill gravels of North London, where, however, the chert is vastly more abundant and in much larger fragments than in the Barton Pebble Bed. The record, however, is based, as far as I can learn, on a single locality—Stanners Hill, near Woking—where the overlying Barton Sands are not present above the pebble-bed, which here forms the hill-top. This leaves an uncomfortable doubt as to the possibility of a later introduction of the chert, since it is common in the Plateau Gravels of the area. I think it may prove possible to distinguish the chert pebbles in the Stanners Hill shingle from those of the Plateau Gravels, but it is clearly desirable that new records should be made from places where the Barton Sand is in situ above. I should, therefore, be grateful if any of your readers could direct my attention either to existing exposures which show the pebble-bed or to places where excavation might be advantageously undertaken. I have written this letter in the hope also that it will lead to a careful scrutiny of any temporary excavations which may be visible from time to time.

J. F. KIRKALDY.

KING'S COLLEGE,
LONDON.
4th April, 1932.

The late Professor J. W. Gregory, F.R.S.

For some time past, for good reasons, the practice of publishing obituary notices in the GEOLOGICAL MAGAZINE has been discontinued. It seems impossible, however, to pass over in silence the tragic death of Prof. J. W. Gregory, who, as announced in *The Times*, was drowned in northern Peru in the middle of last month. For many years Professor Gregory has been one of the Editorial Advisers of this Magazine: he often gave wise counsel, as well as unswerving support at a critical time, some twelve years ago, when the very existence of the Magazine hung in the balance. His work as geologist and explorer is too well known to need detailed mention here, and the Editor can only express his deep personal regret at the loss of so valued a colleague.